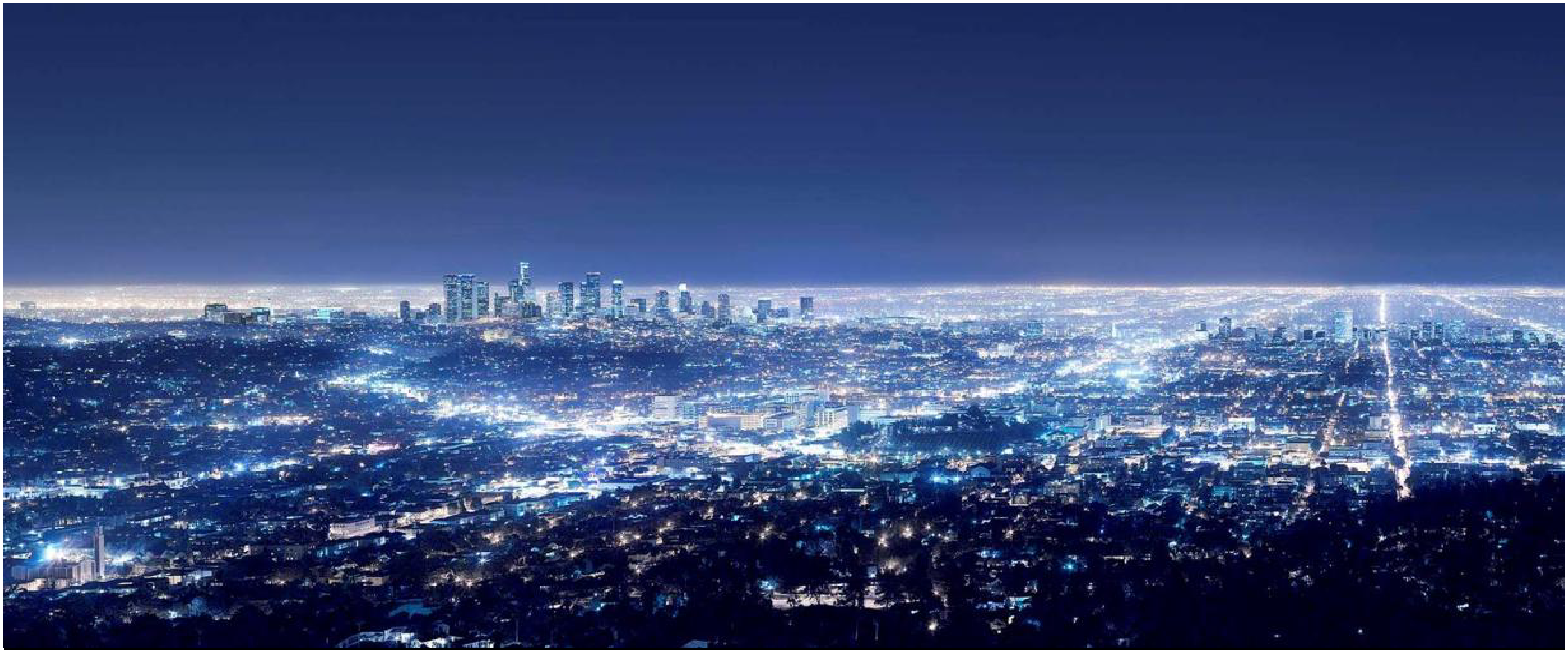
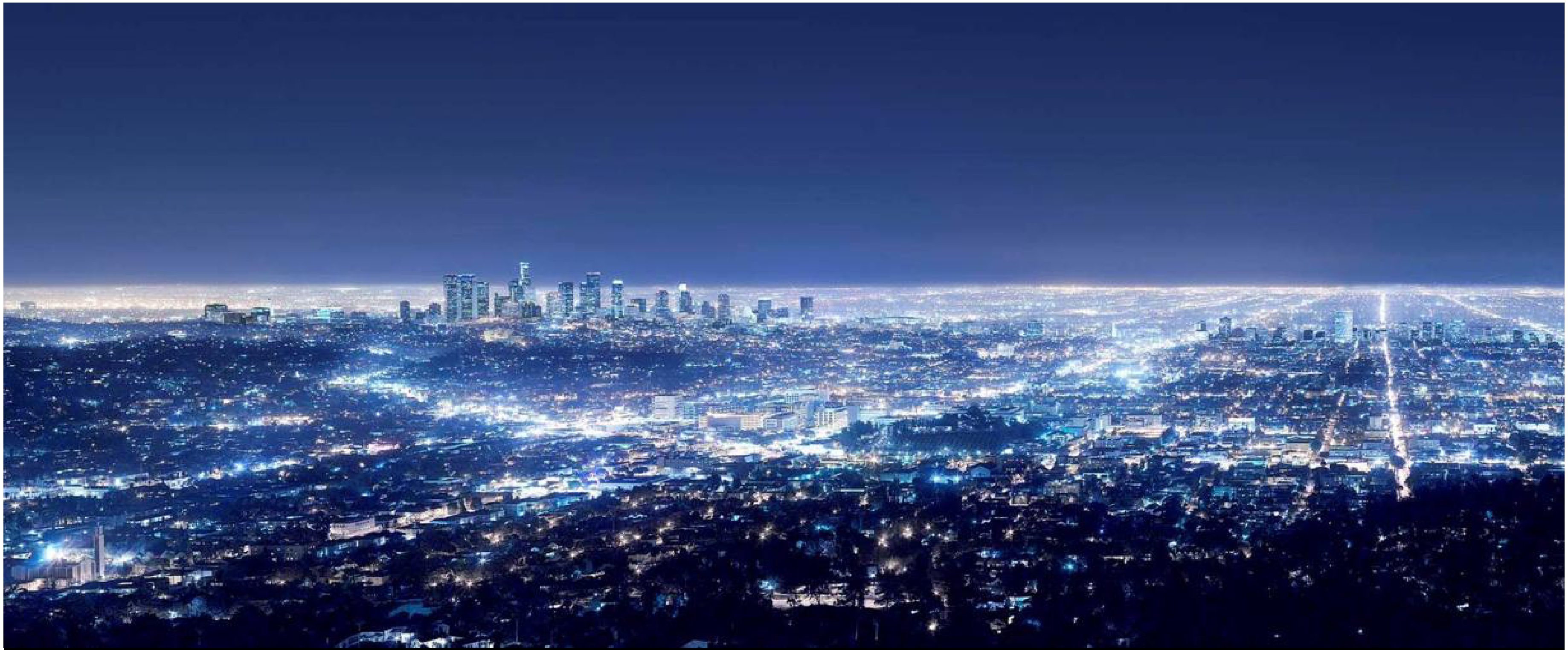


Antony RAJA, INOPC - 08/08/2013

RET 670
Differential Protection



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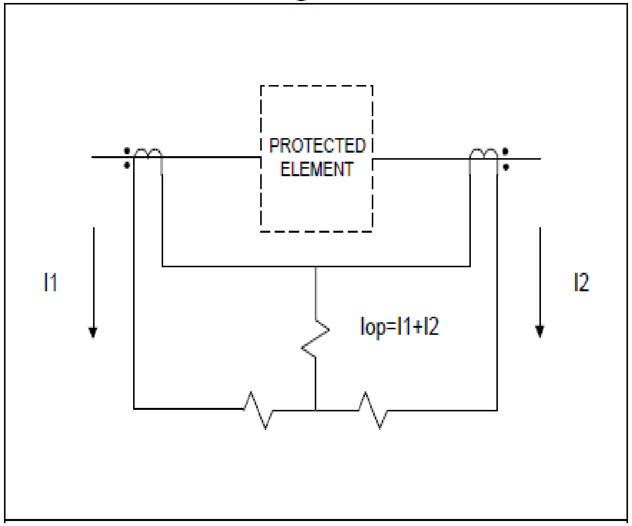
RET 670
Differential Protection Basics

BASIC CURRENT DIFFERENTIAL RELAYING

Current differential relaying is applied to protect many elements of a power system. The simplest example of a current differential relaying scheme is shown in Figure 1. The protected element might be a length of circuit conductor, a generator winding, a bus section, etc. From Figure 1 it can be seen that current differential relaying is a basic application of Kirchhoff's Current Law. The relay operates on the sum of the currents flowing in the CT secondaries, $I_1 + I_2$. For through current conditions, such as load or an external fault, the currents in the two CT's will be equal in magnitude and opposite in phase (assuming the CT's have the same ratio and are properly connected), and there will be no current flow in the relay operate coil [1].

Figure 1



Should a short circuit occur within the protected section between the two CT's, current will flow through the operate circuit causing the relay to issue a trip output.

To improve the selectivity and security of the current differential scheme, it is often designed as a percentage restraint differential relay. In a percentage restraint current differential relay, the operating current is the vector sum of the CT currents.

$$I_{operate} = |\, I_1 + I_2 \,|$$

This operating current must be greater than some percentage (K1) of the restraint quantity which is derived from the sum of the magnitude of the individual CT currents. A typical restraint current could be:

$$I_{restraint} = k^*[\, |\, I_1 \,| + |\, I_2 \,| \,]$$

The operating characteristic of the percentage restraint current differential relay with a slope of K1 is shown in Figure 2.

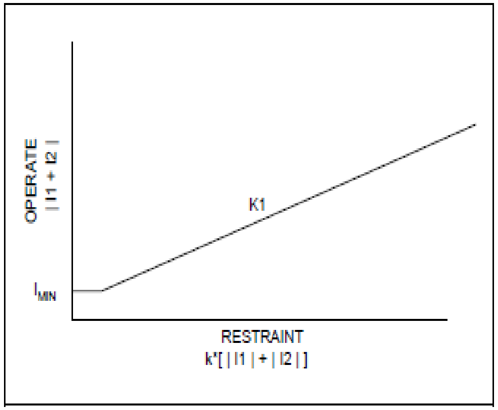
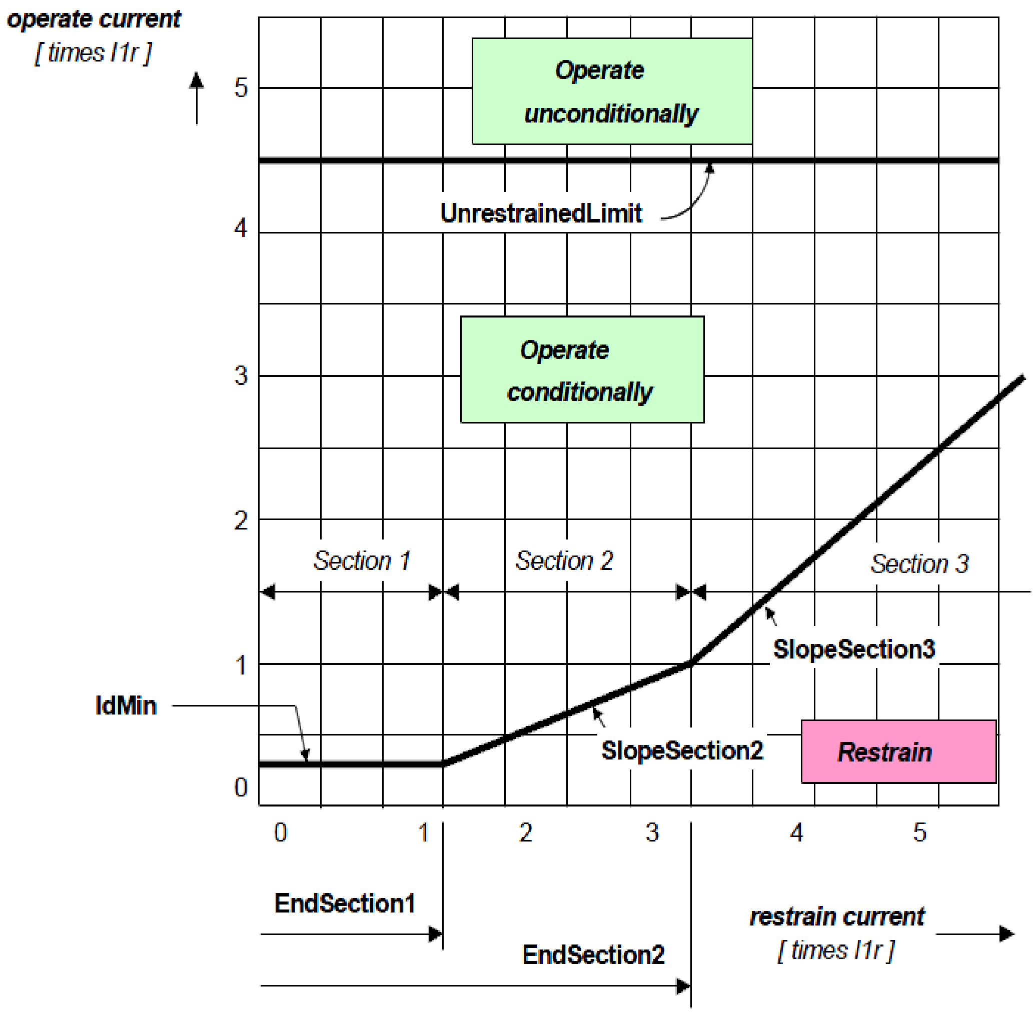


Figure 2

Operate - Restrain Differential Characteristics



Section 1: This is the most sensitive part on the characteristic. In section 1, normal currents flow through the protected circuit and its current transformers, and risk for higher false differential currents is relatively low. Un-compensated on-load tap-changer is a typical reason for existence of the false differential currents in this section. Slope in section 1 is always zero percent.

Section 2: In section 2, a certain minor slope is introduced which is supposed to cope with false differential currents proportional to higher than normal currents through the current transformers.

Section 3: The more pronounced slope in section 3 is designed to result in a higher tolerance to substantial current transformer saturation at high through-fault currents, which may be expected in this section.

The operate - restrain characteristic should be designed so that it can be expected that:

- for internal faults, the operate (differential) currents are always safely, i.e. with a good margin, above the operate - restrain characteristic
- for external faults, the false (spurious) operate currents are safely, i.e. with a good margin, below the operate - restrain characteristic

where:

$$slope = \frac{\Delta Ioperate}{\Delta Irestrain} \cdot 100\%$$

RET 670

Differential Protection

Basics for Differential Protection

- Ratio compensation of injected current should match with the primary and secondary
- Phase Shift should be considered, as by default there will be a 180 phase shift
- Vector group is an important factor as to which vector group is selected for example d1(30) lag etc.

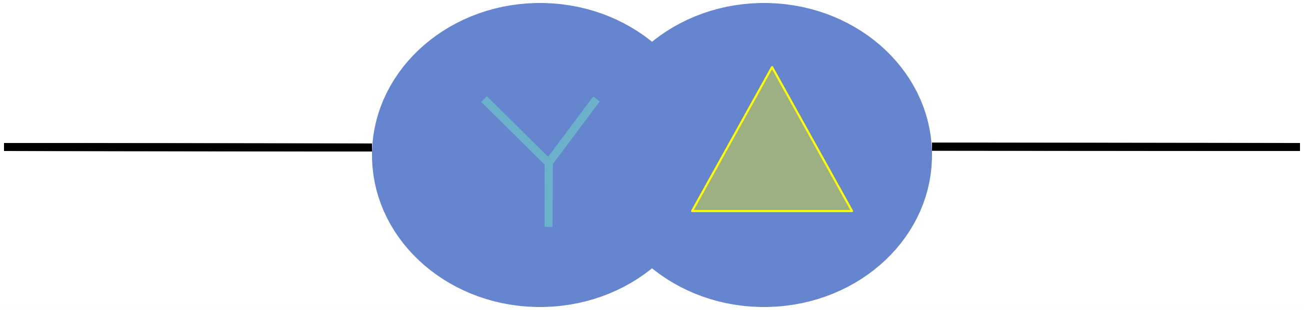
RET 670

Differential Protection

For example let us consider a Star / Delta transformer of 220kV / 110kV and having a current of 800 / 2500A

220kV / 110kV

800/1 A 2500/1 A



RET 670

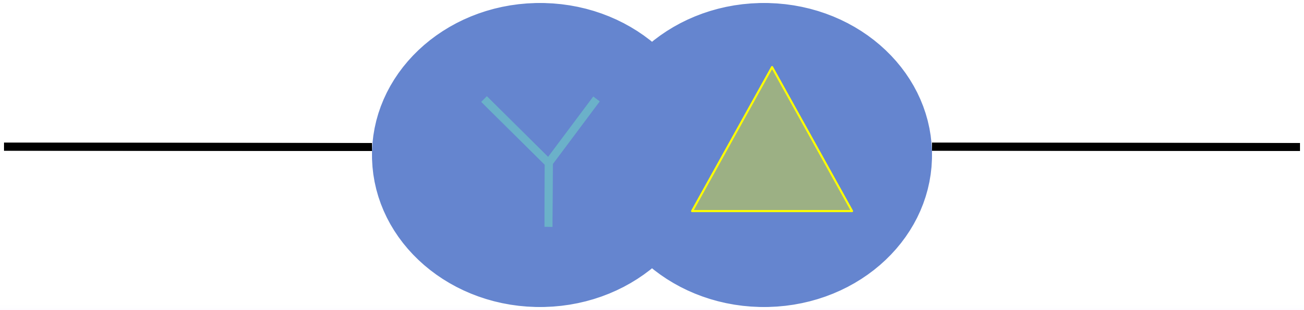
Differential Protection

Condition 1 is satisfied i.e. <u>Ratio Compensation</u>

- For 100mA in primary the primary current is 800 x 0.1= 80A

- But the secondary ratio is 2500 / 1, so in order to match the secondary current with the primary we consider 2500 x (X) = 80A

  i.e. X = 80/2500 => <u>32mA</u>



RET 670

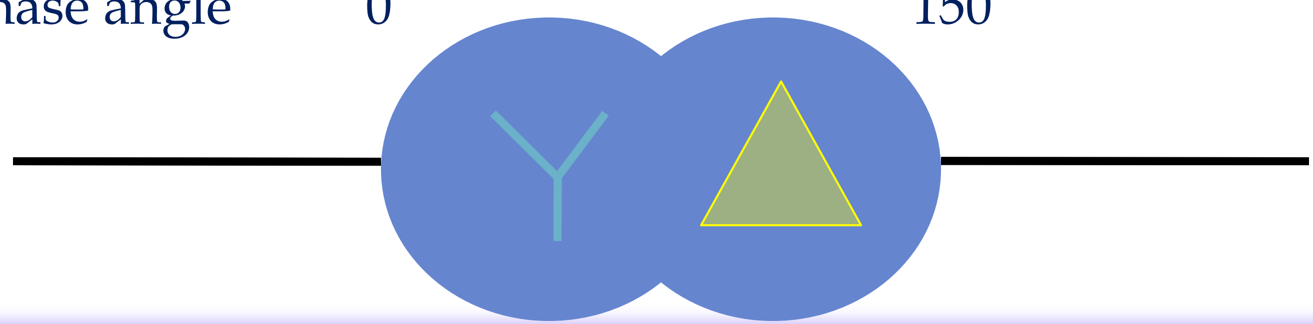
Differential Protection

Condition 2 is satisfied i.e. Phase Shift by the specified vector group

- The secondary is delta (DY1) and its 30 degrees lag from the primary, so the phase shift is 180-30 = 150.

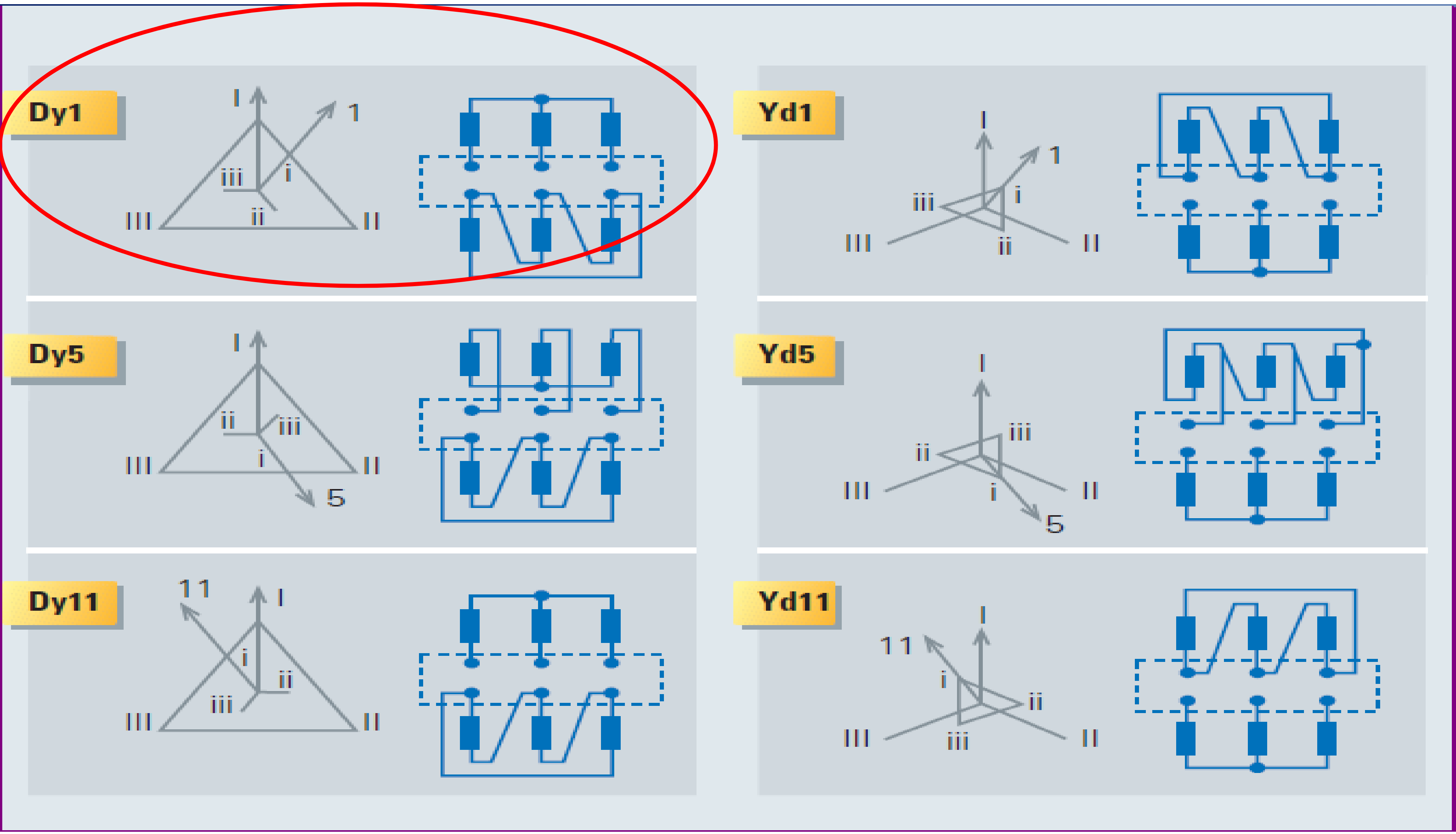
- So the phase angle that has to be set for primary is 0 and the secondary is 150 for R phase and so on.

Phase angle 0 150



RET 670

Vector group



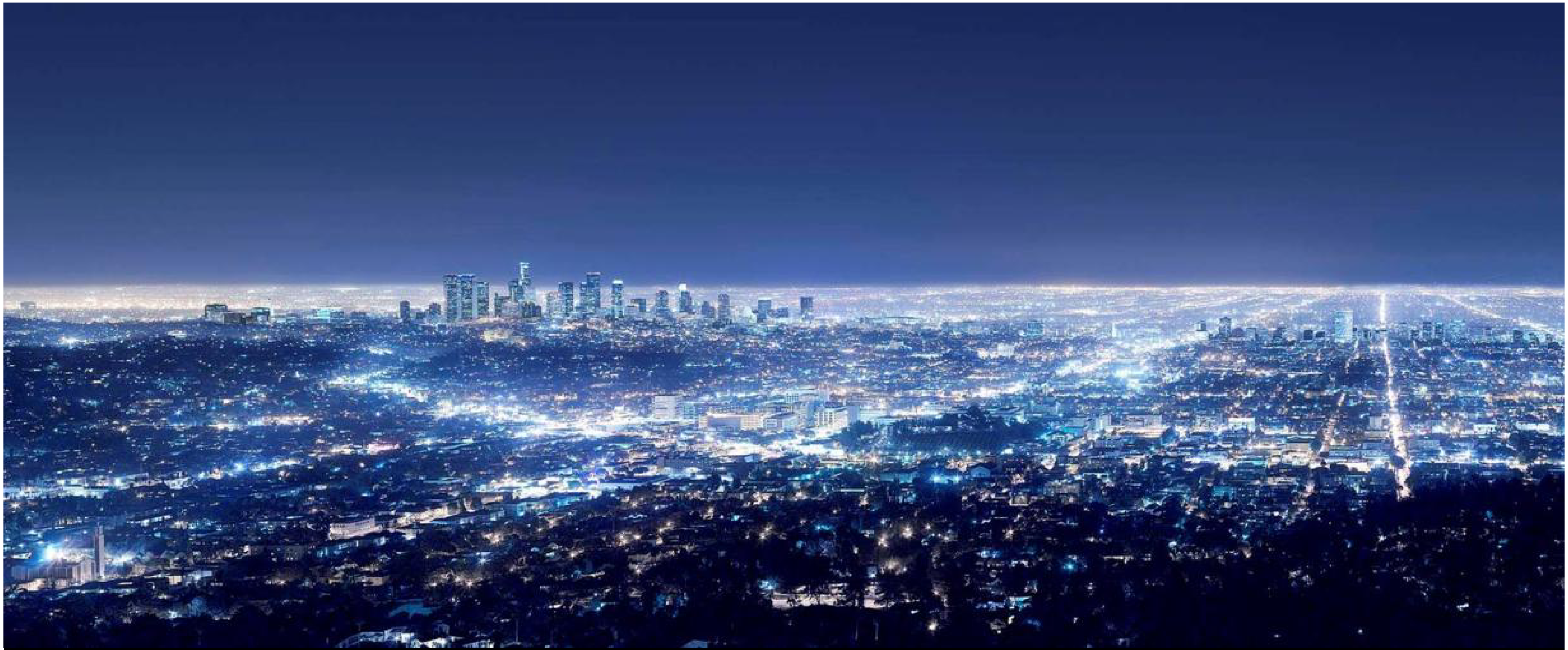
RET 670

Differential Protection

- Using the CMC gives us the basic understanding of differential protection.

- The values of IBIAS & IDIFF can be checked in the relay by going to Test menu then to Function status then to Differential protection, then to TransformerDiff3wind.

- The testing can be performed by quick CMC by varying the values of magnitude and phase angle.



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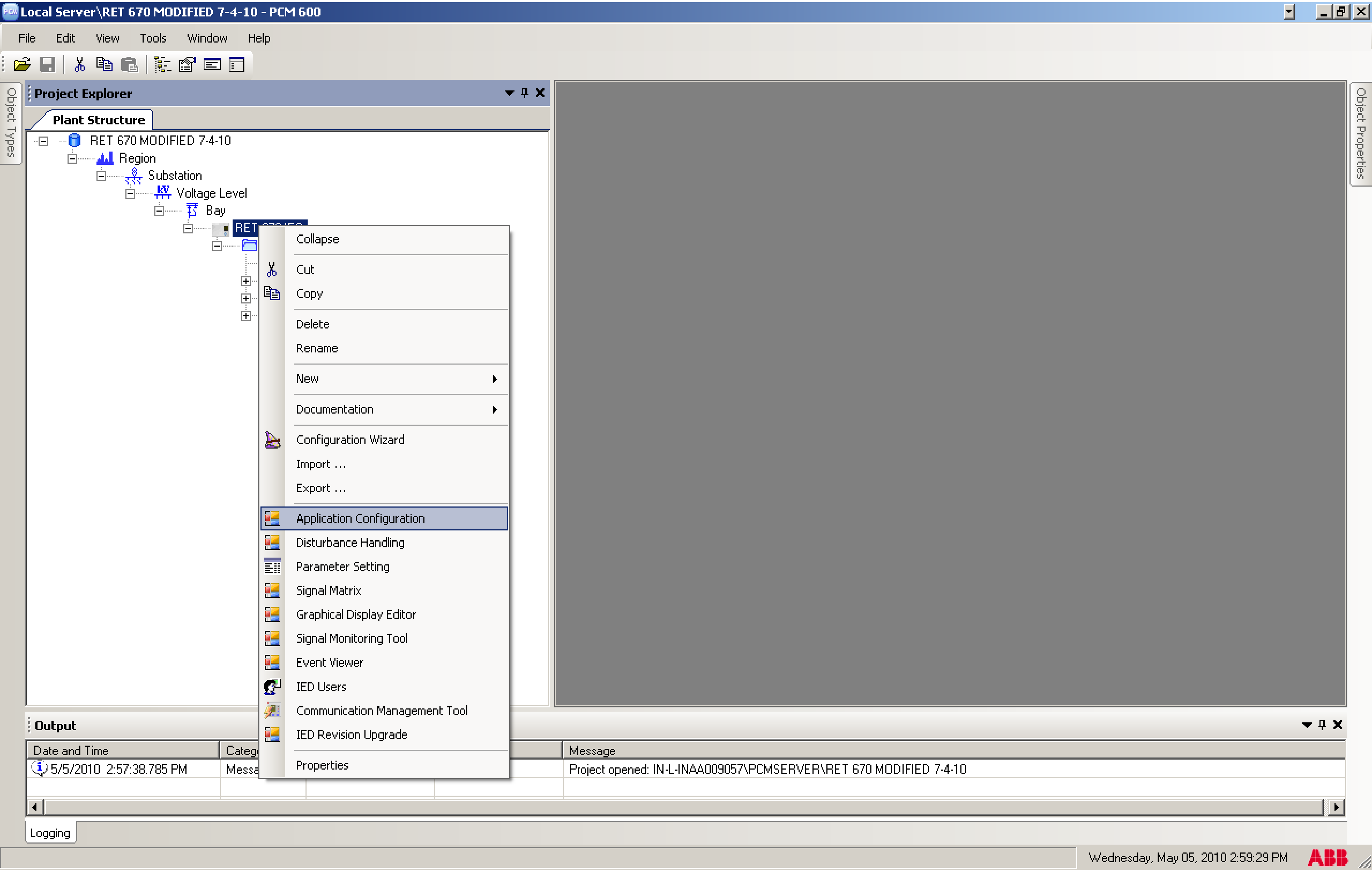
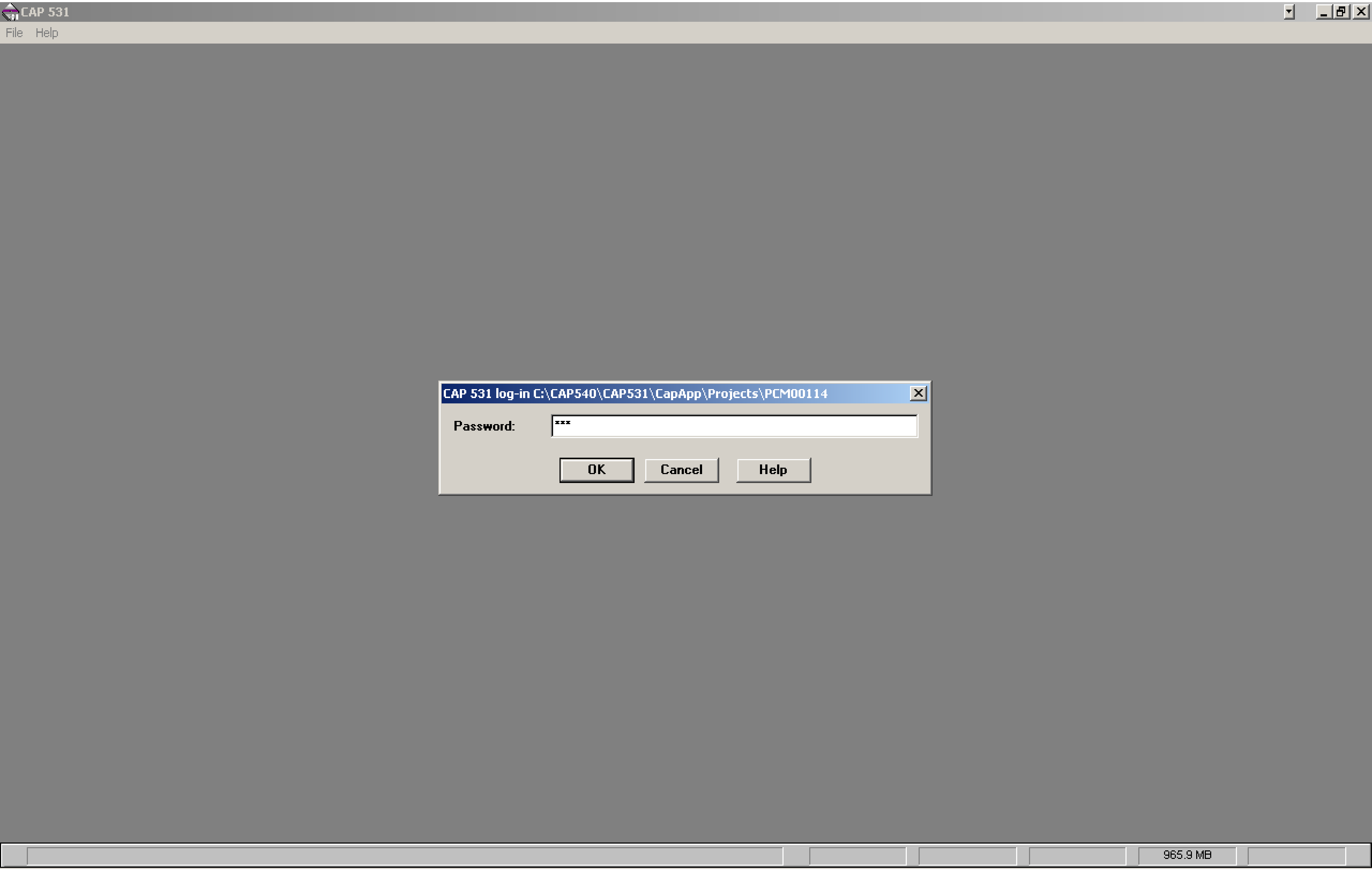
RET 670

Parameters settings, App Configuration tool, Testing of Differential using Omicron 356 in Quick CMC mode

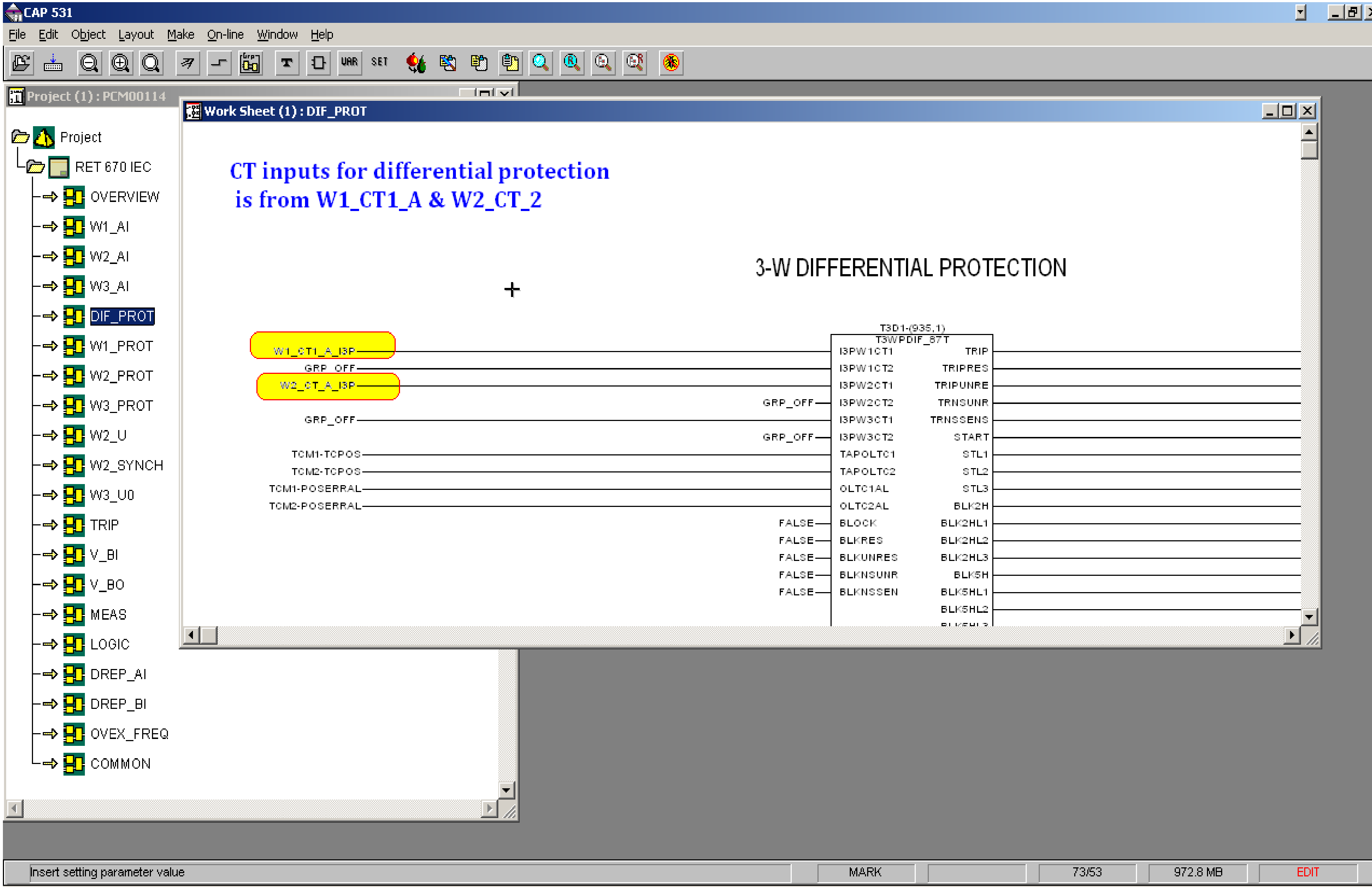
RET 670 – ACT TOOL



RET 670 – ACT TOOL

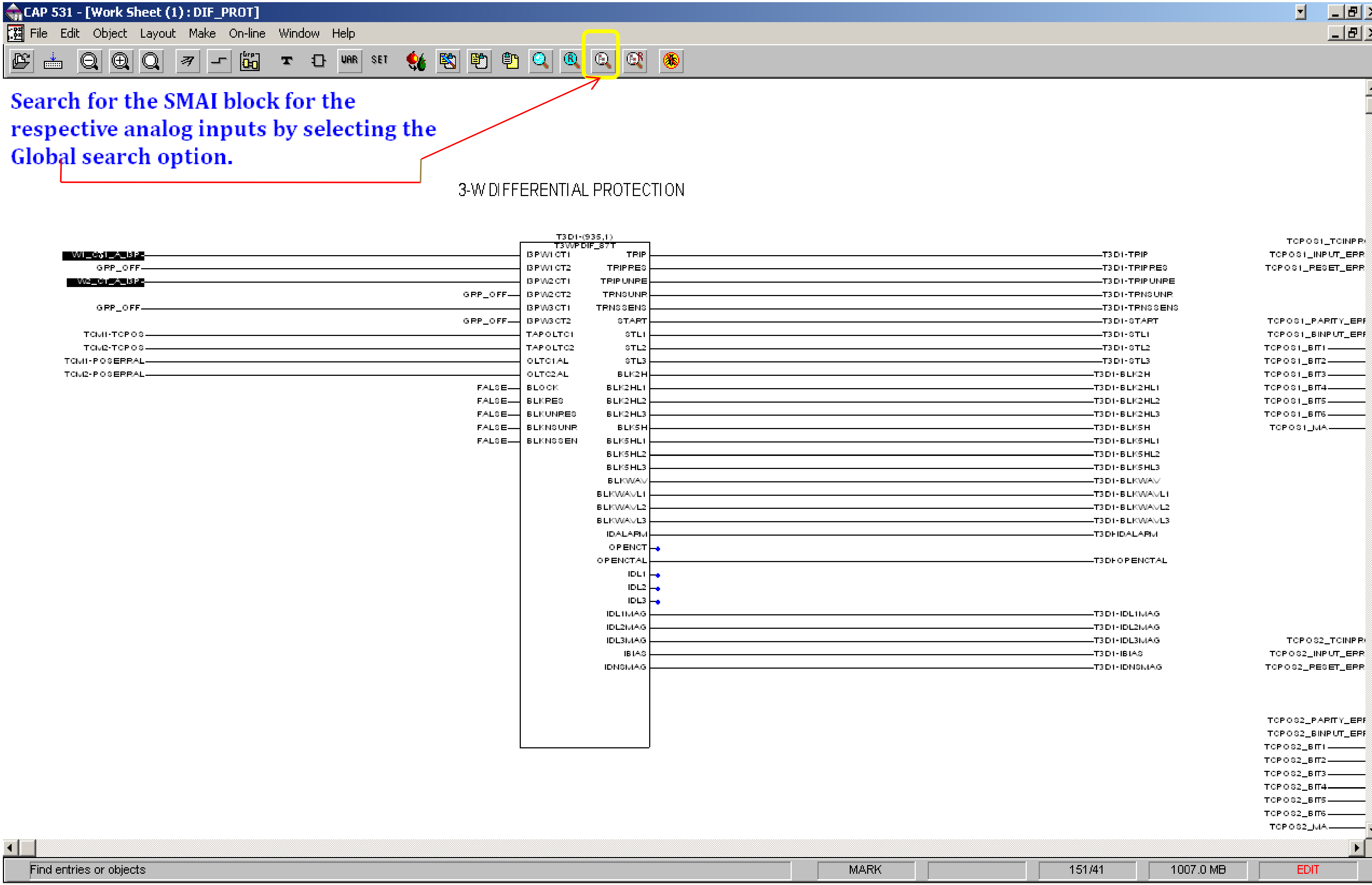


RET 670 – CAP 531

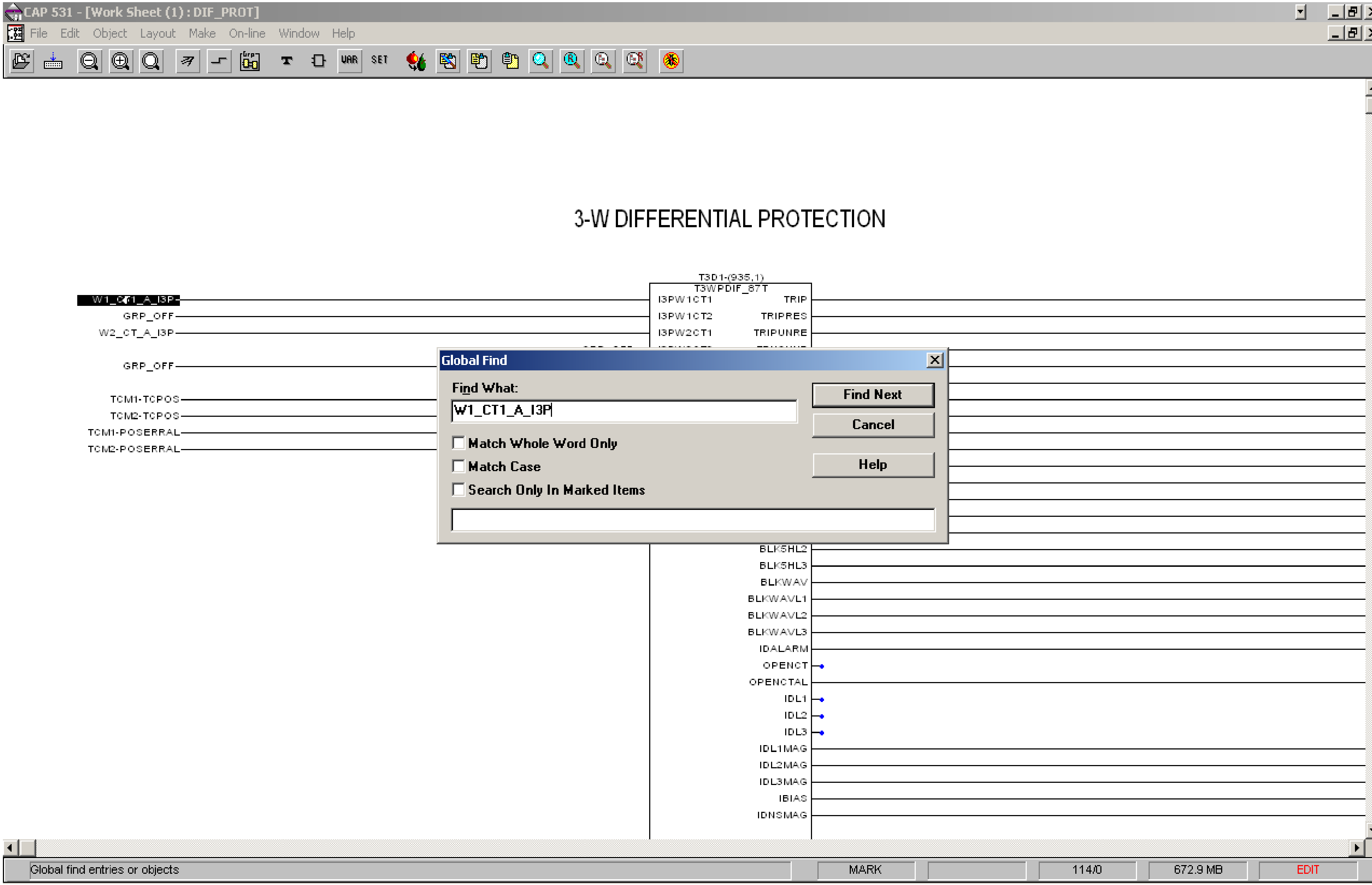


RET 670 – CAP 531

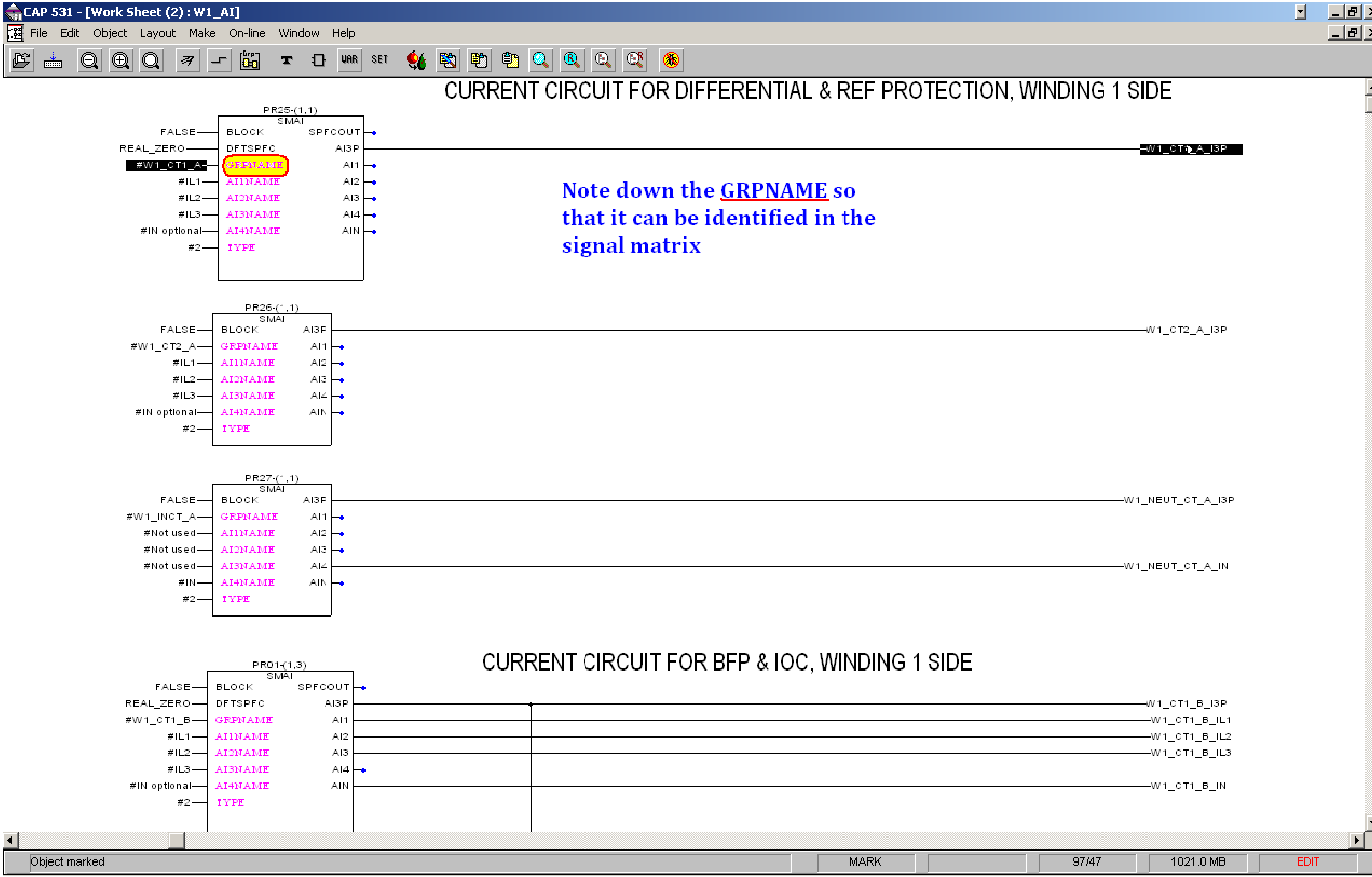
Search for the SMAI block for the respective analog inputs by selecting the Global search option.



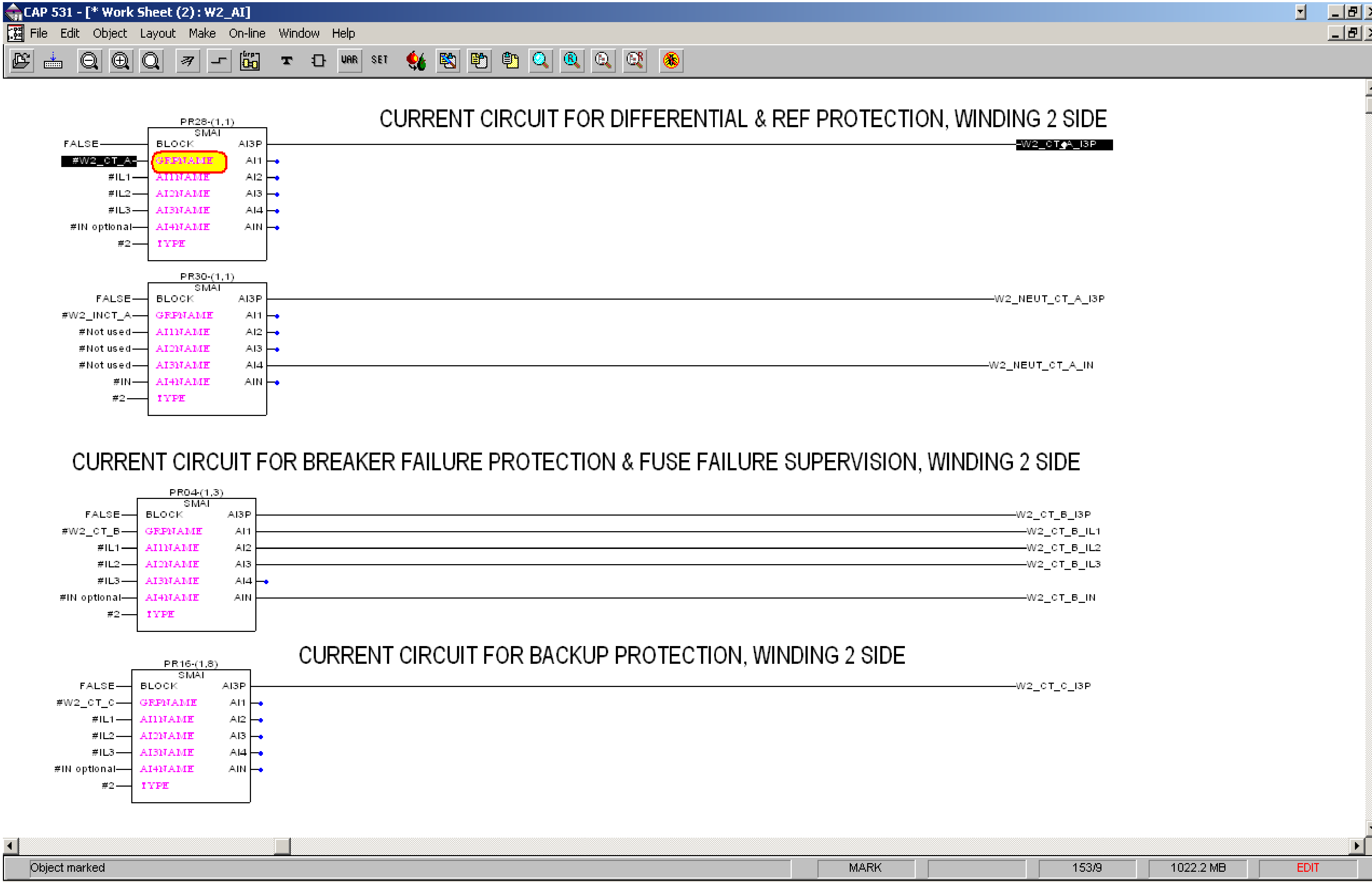
RET 670 – CAP 531



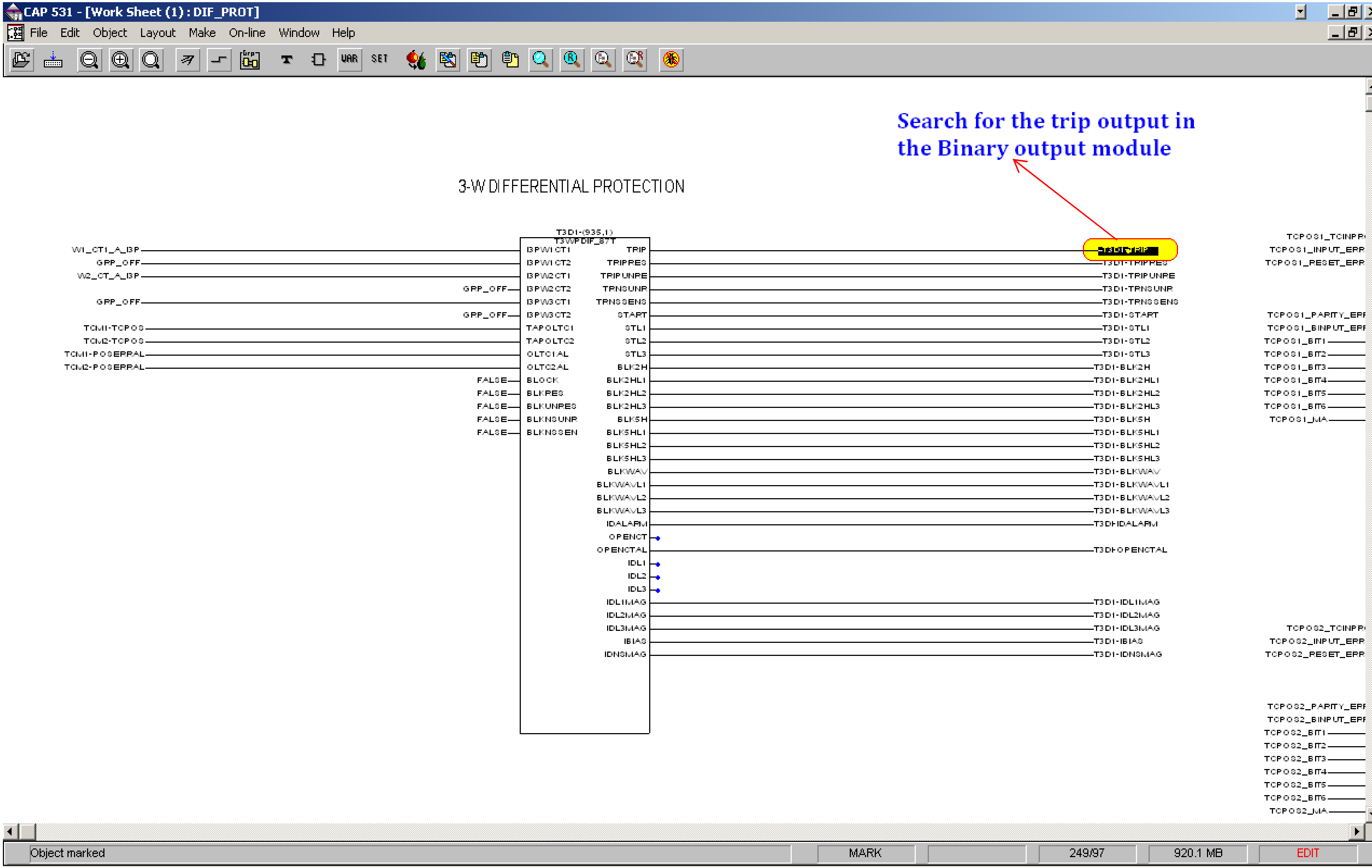
RET 670 – CAP 531



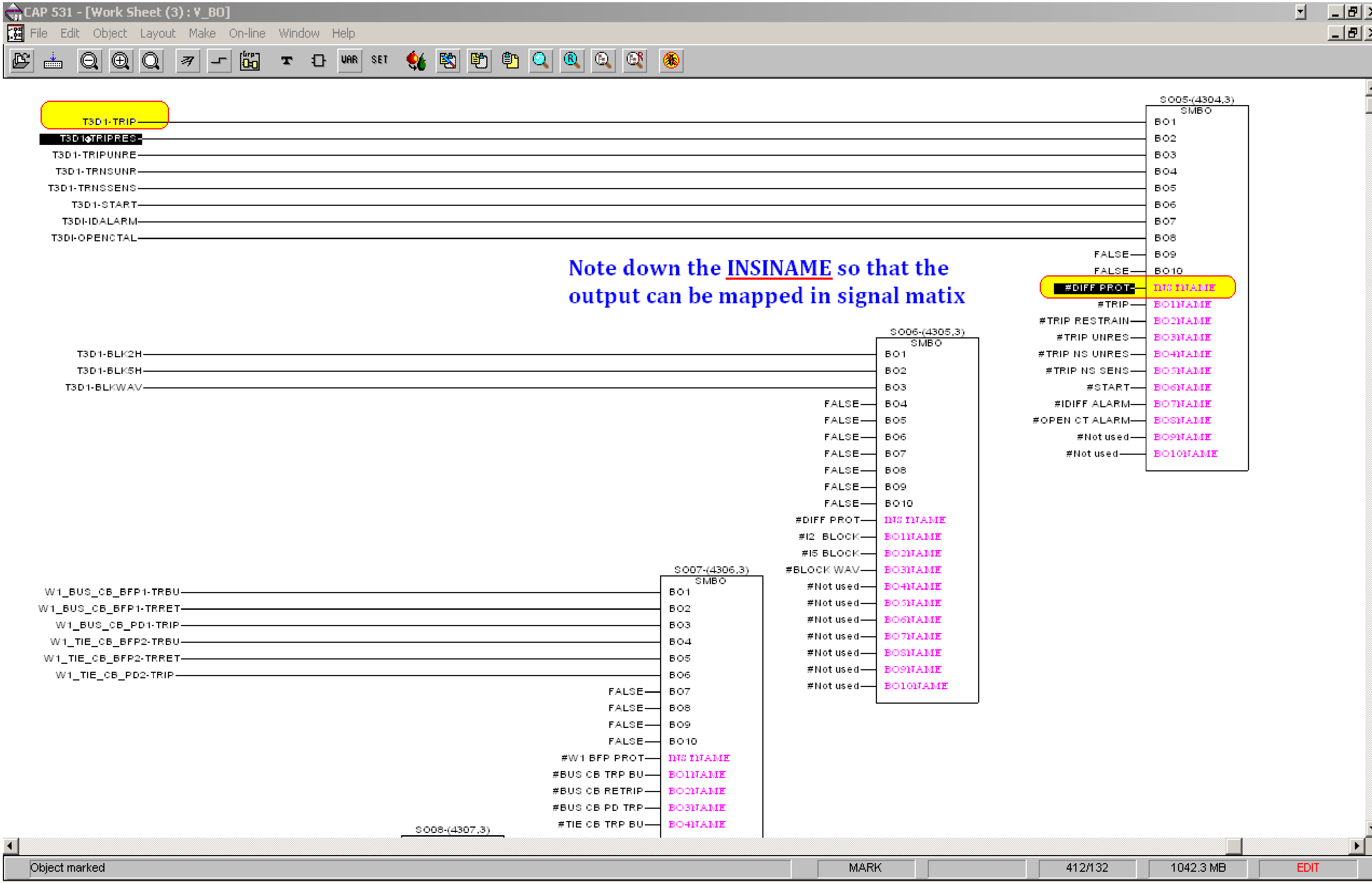
RET 670 – CAP 531



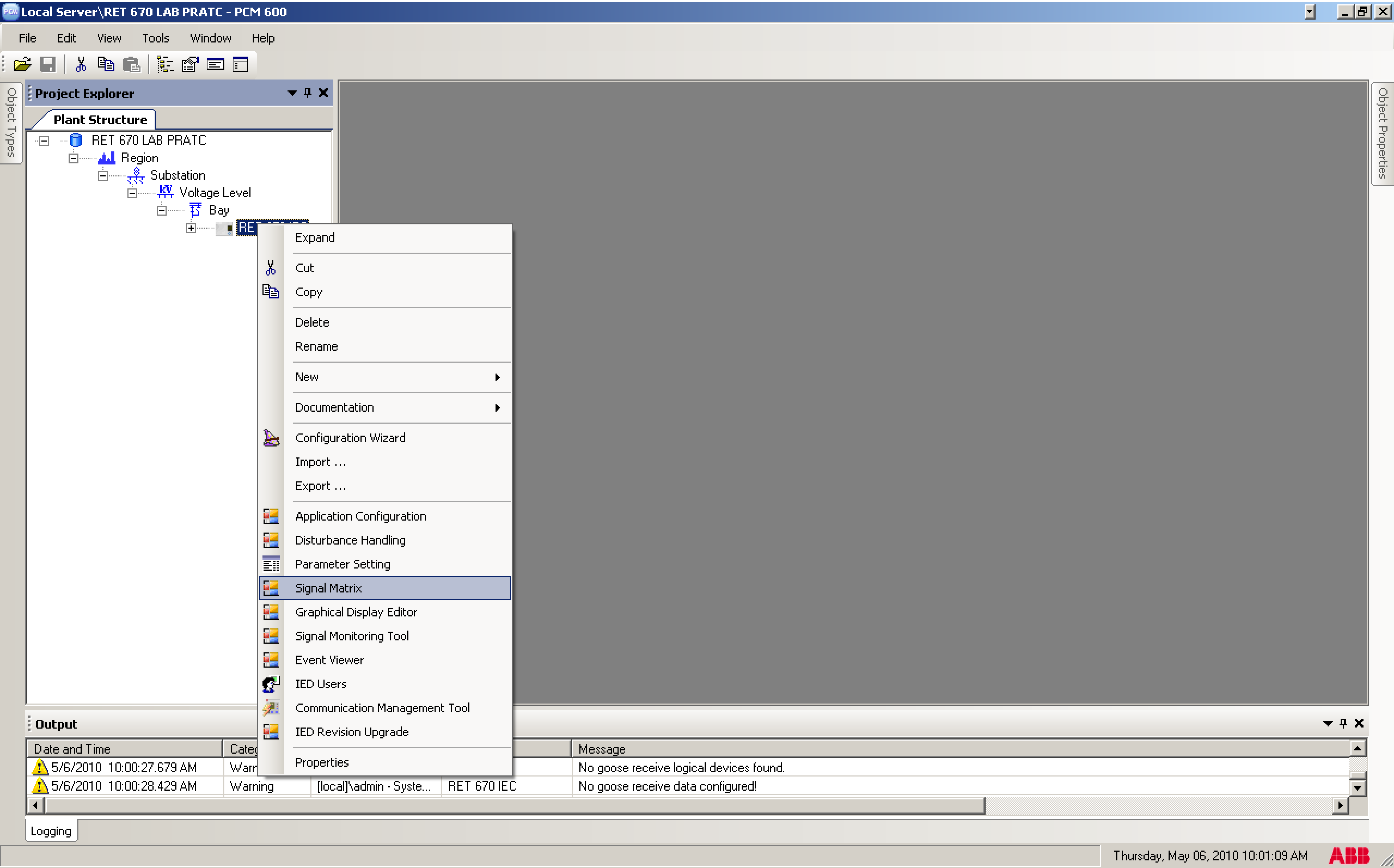
RET 670 – CAP 531



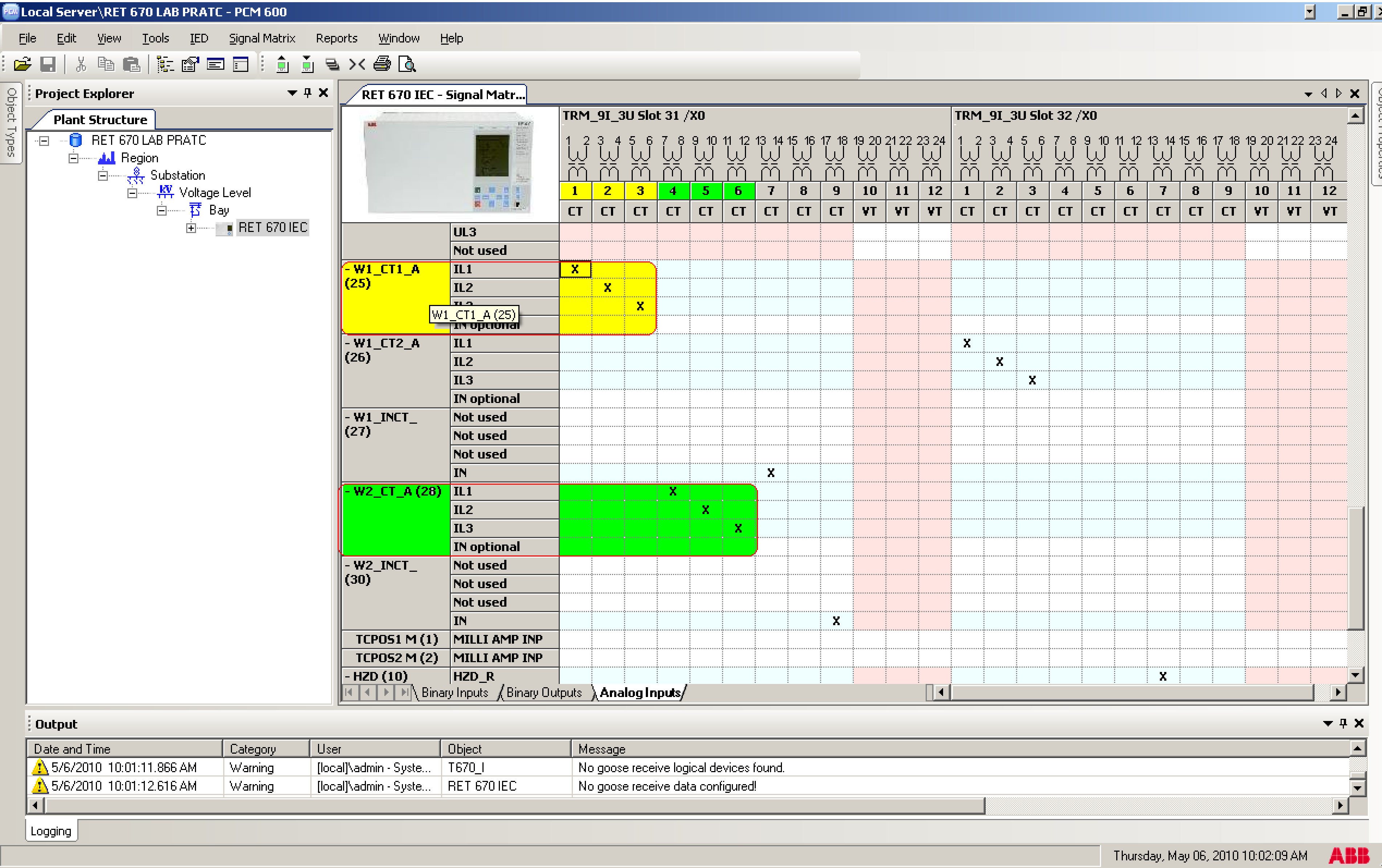
RET 670 – CAP 531



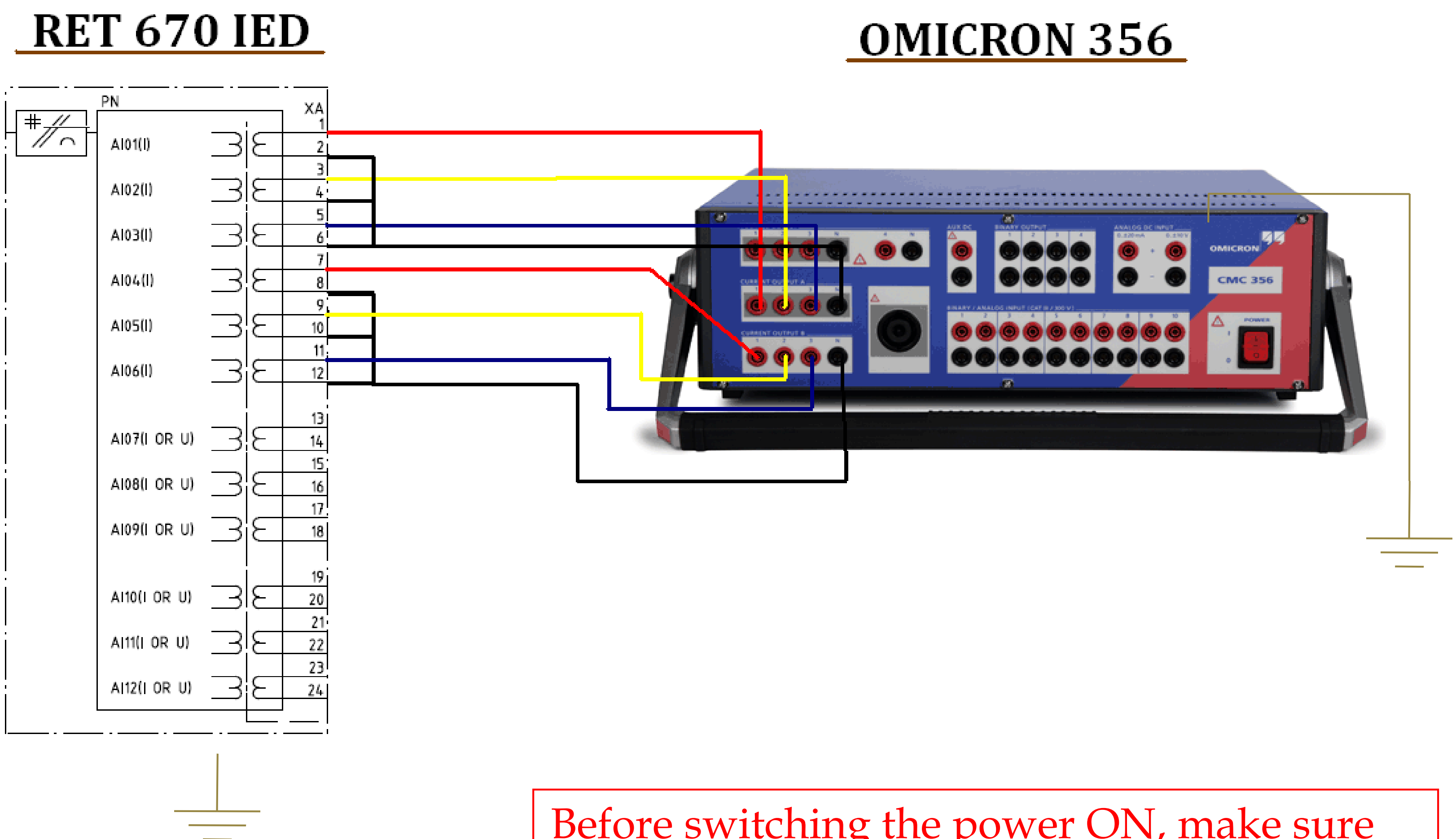
RET 670 – Signal Matrix



RET 670 – Signal Matrix

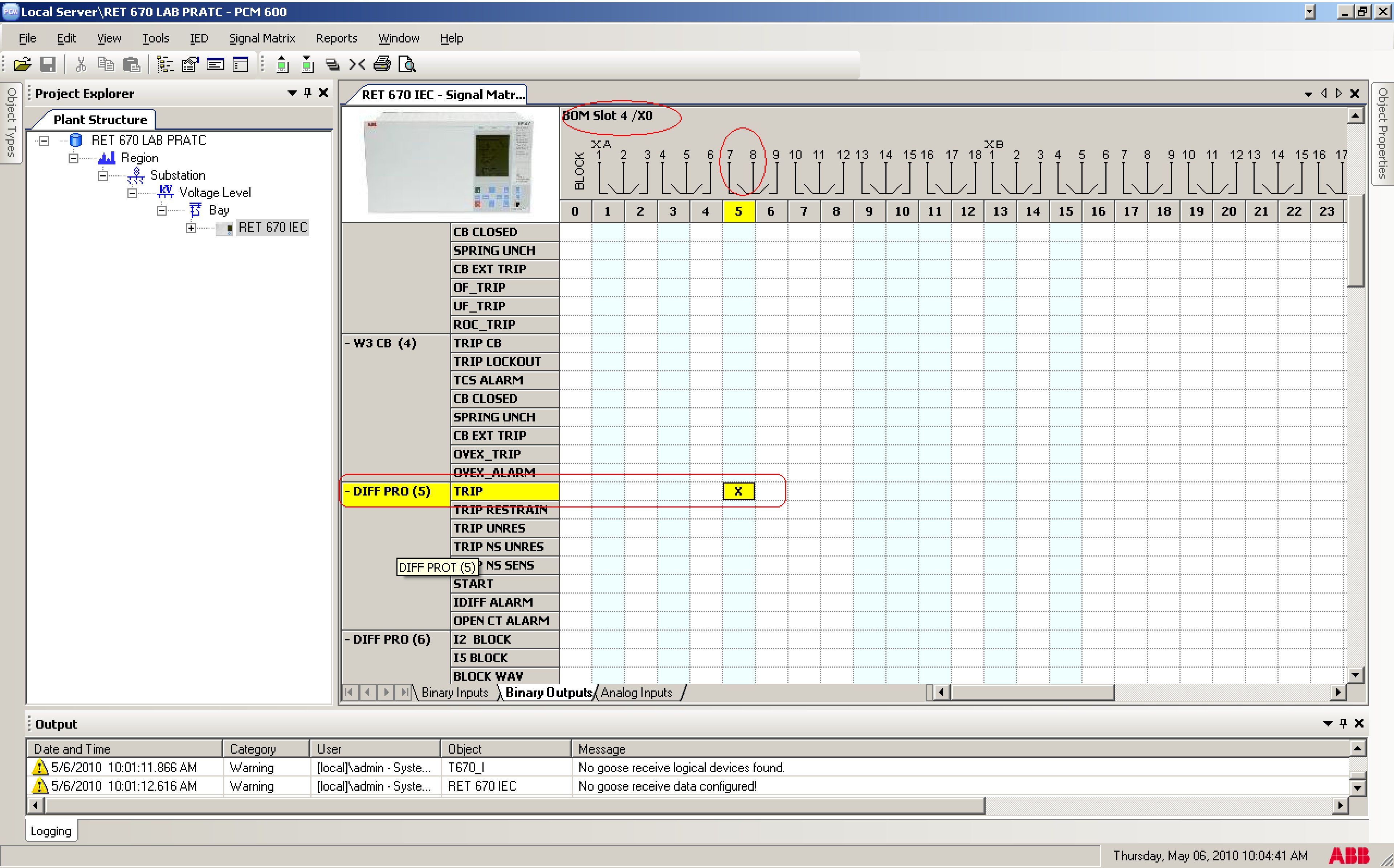


CT Connections between the IED and Omicron 356



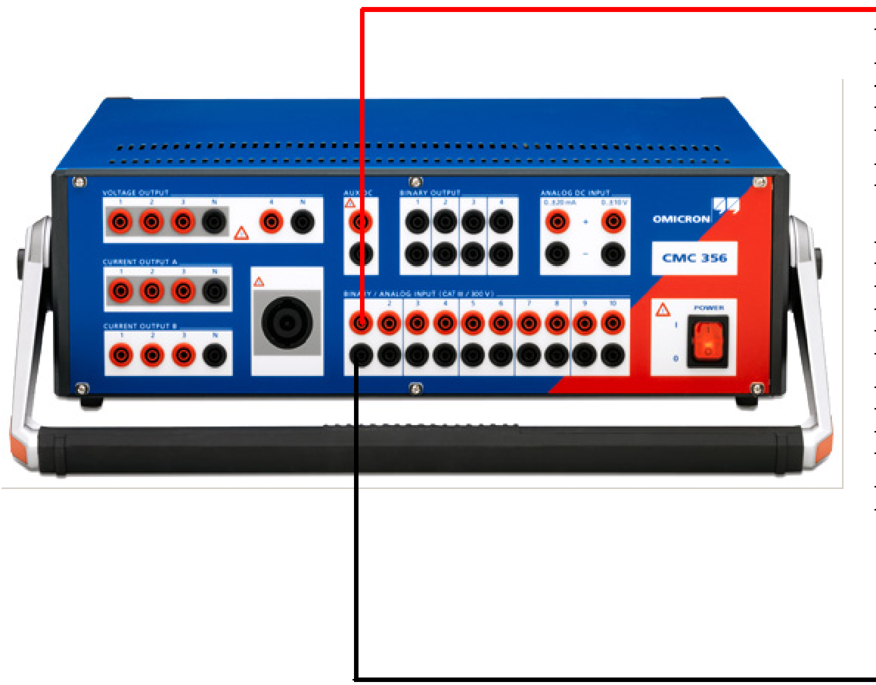
Before switching the power ON, make sure that the IED & Omicron is earthed

RET 670 – Signal Matrix



Feedback from IED to Omicron

Connection for feedback from IED to Omicron



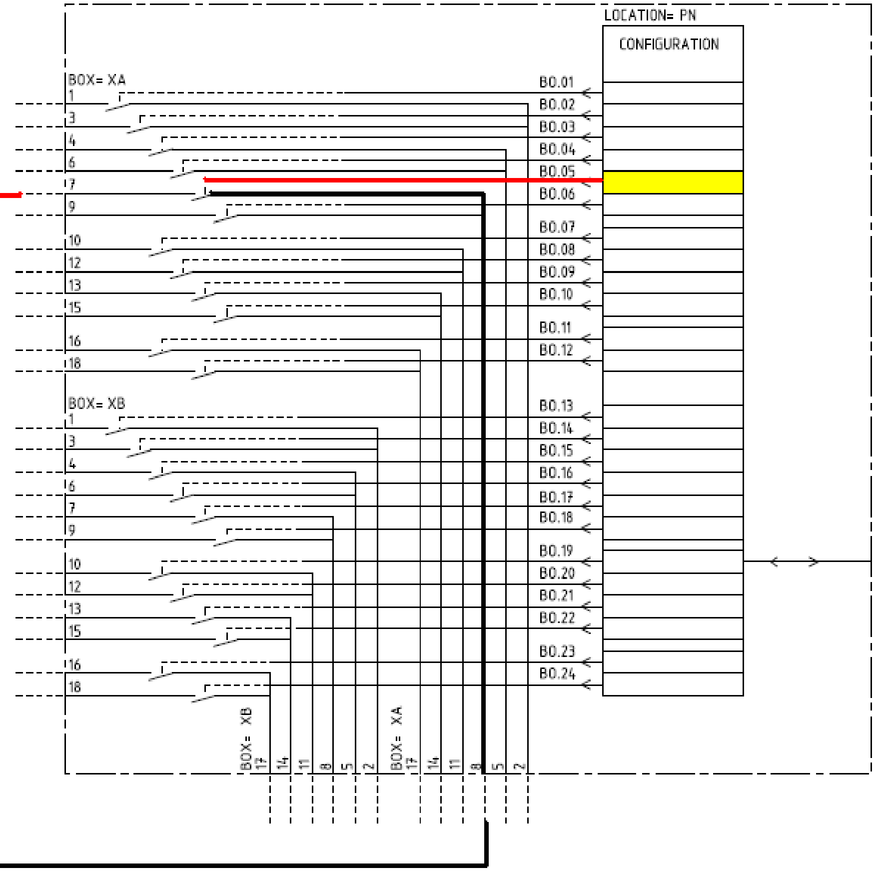


Figure 25: *Binary output module (BOM). Output contacts named XA corresponds to rear position X31, X41 etc. and output contacts named XB to rear position X32, X42, etc.*

RET 670 – CT RATIO

Local Server\RET 670 LAB 24-03-10 - PCM 600

File Edit View Tools IED Window Help

Project Explorer

Plant Structure

- RET 670 LAB 24-03-10
  - Region
    - Substation
      - Voltage Level
        - Bay
          - RET 670 IEC
            - Settings
              - Activate setting group
              - Time
              - General settings
                - Power system
                - Communication
                - Analog modules
                  - AnalogInpu
                  - AnalogInpu
                  - Reference
                  - 3PhaseAn
                  - 3PhAnalog
                - I/O modules
                - HMI
                - Differential prote
                - Current protectio
                - Voltage protecti
                - Control
                - Monitoring
                - Metering
              - Setting group N1

RET 670 IEC - Parameter ...

Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
NAMECH1		TRM40-CH1			13 character(s)
RatedTrans1		1.0	A	0.1	300.0
CTStarPoint1		ToObject			
CTsec1		1	A	1	10
CTprim1		800	A	1	99999
NAMECH2		TRM40-CH2			13 character(s)
RatedTrans2		1.0	A	0.1	300.0
CTStarPoint2		ToObject			
CTsec2		1	A	1	10
CTprim2		800	A	1	99999
NAMECH3		TRM40-CH3			13 character(s)
RatedTrans3		1.0	A	0.1	300.0
CTStarPoint3		ToObject			
CTsec3		1	A	1	10
CTprim3		800	A	1	99999
NAMECH4		TRM40-CH4			13 character(s)
RatedTrans4		1.0	A	0.1	300.0
CTStarPoint4		ToObject			
CTsec4		1	A	1	10
CTprim4		2500	A	1	99999
NAMECH5		TRM40-CH5			13 character(s)
RatedTrans5		1.0	A	0.1	300.0
CTStarPoint5		ToObject			
CTsec5		1	A	1	10

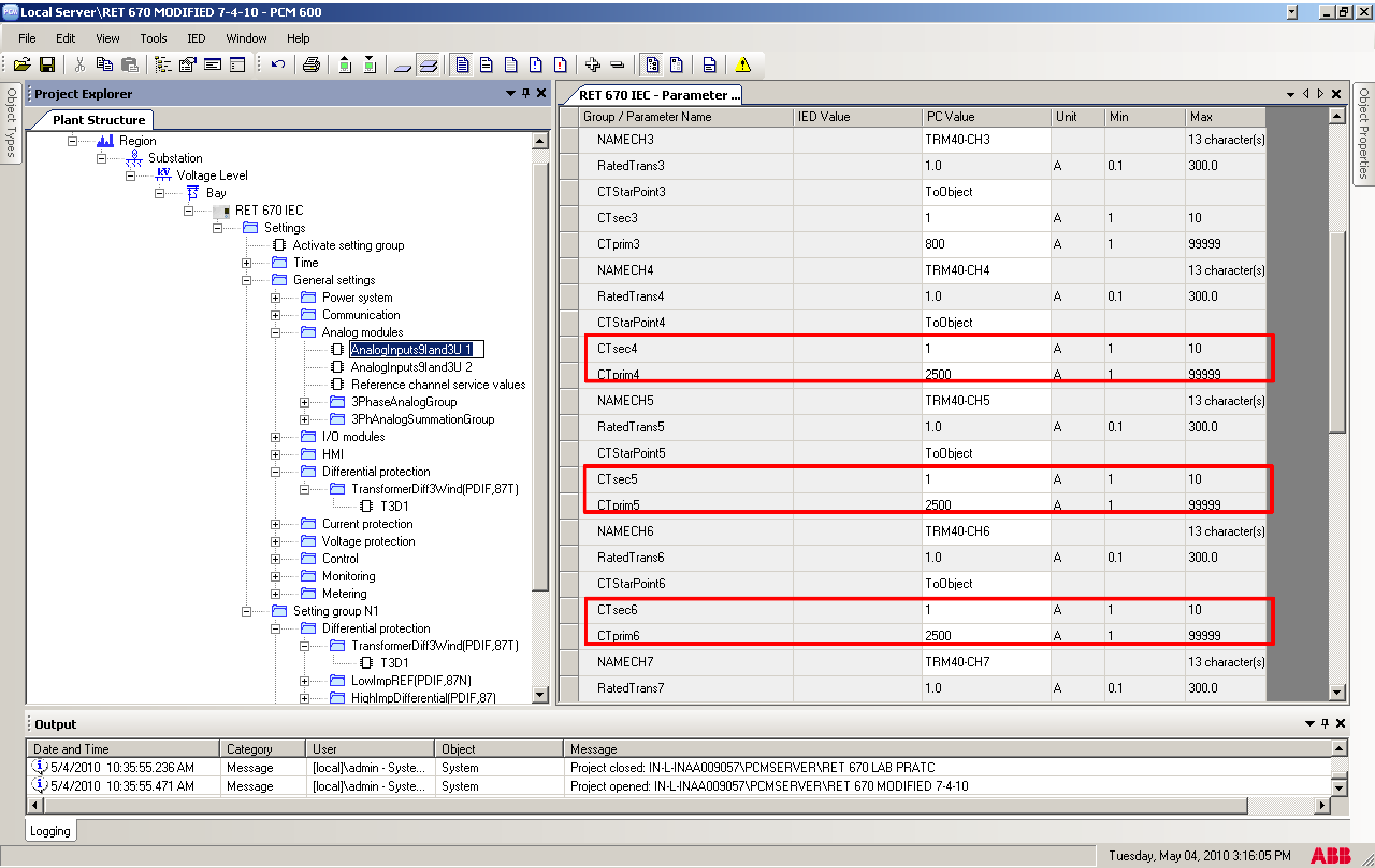
Object Properties

Output

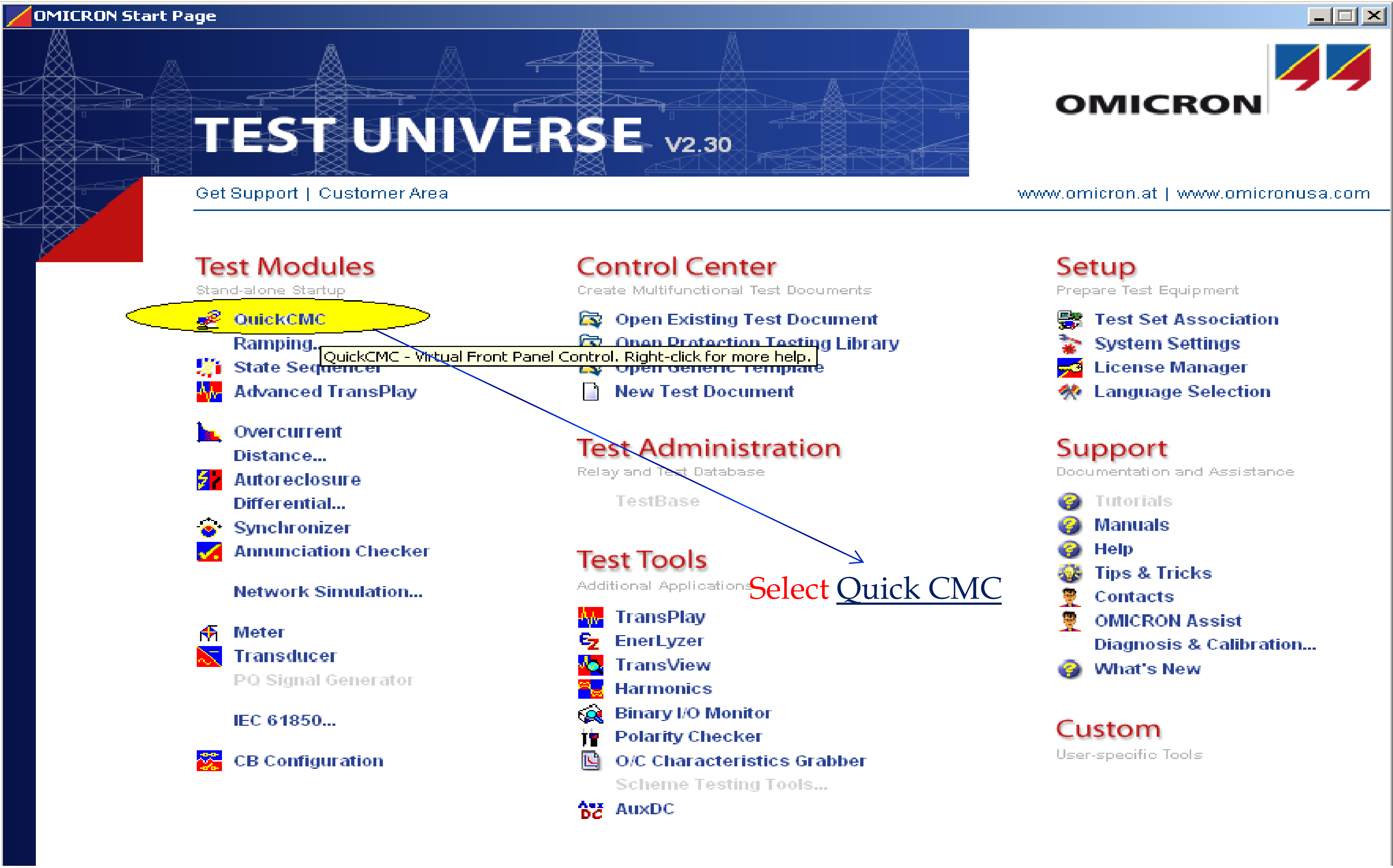
Logging

Wednesday, March 31, 2010 6:11:56 PM ABB

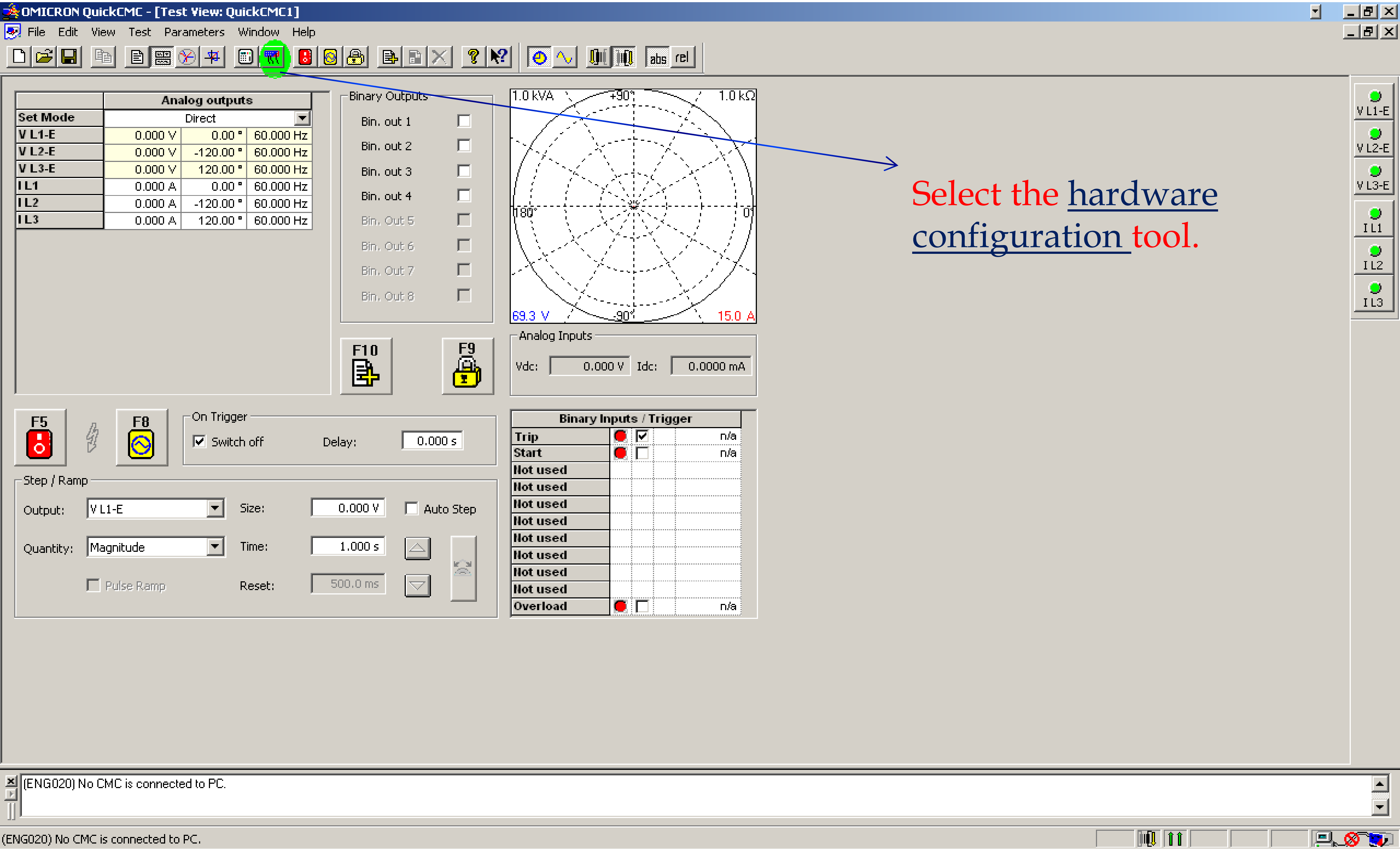
RET 670 – CT RATIO



Using Omicron

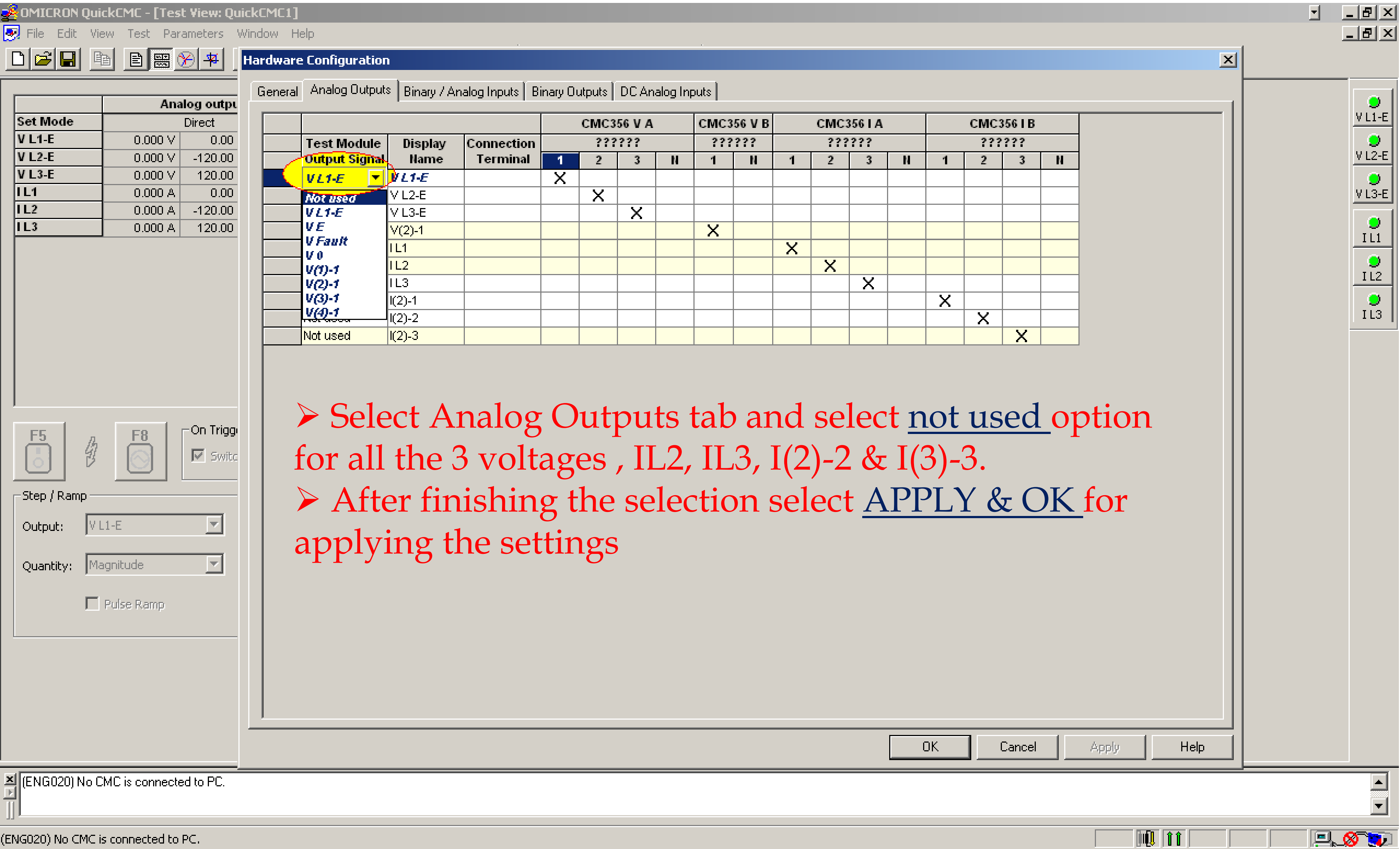


Using Omicron



Select the hardware configuration tool.

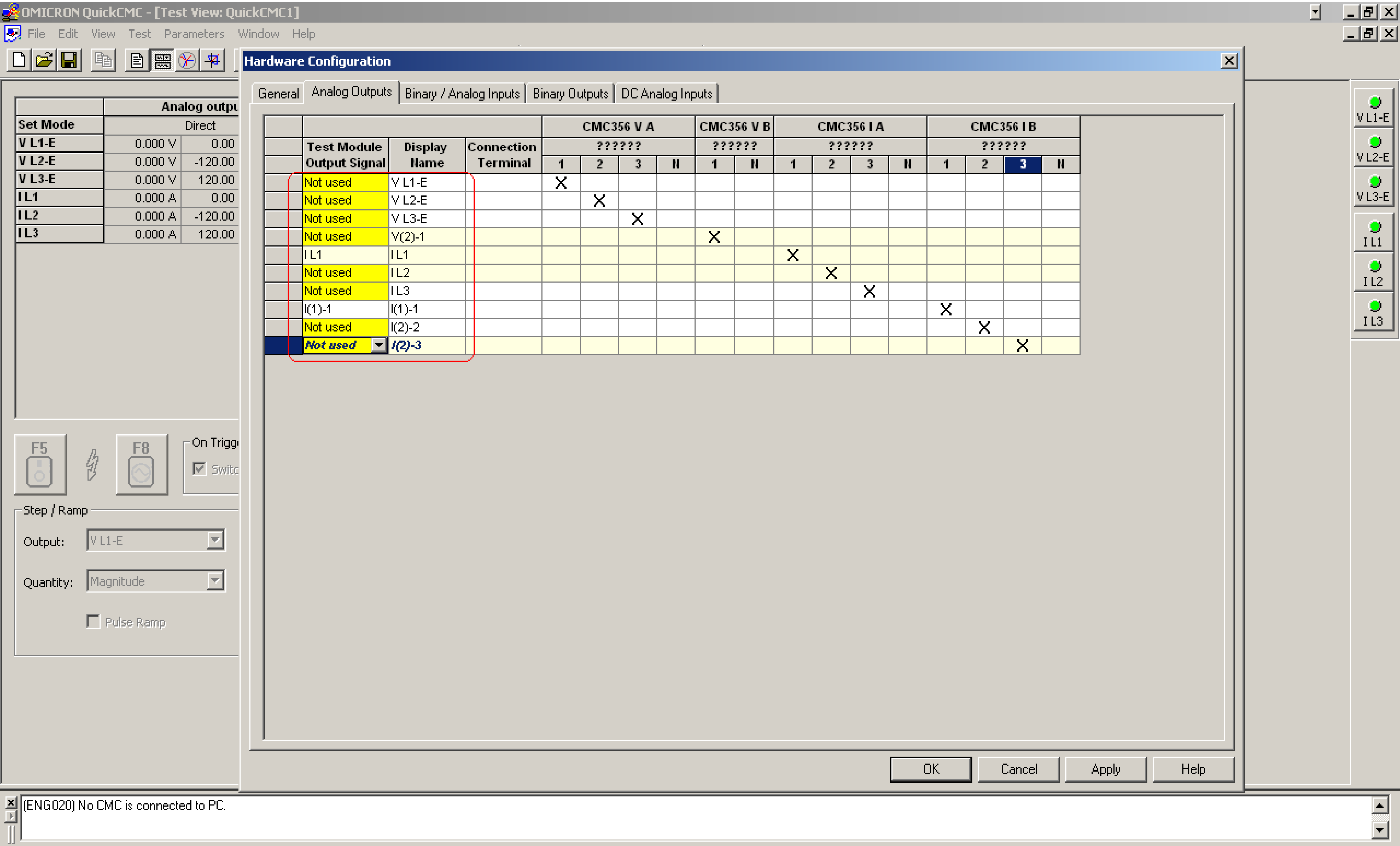
Using Omicron



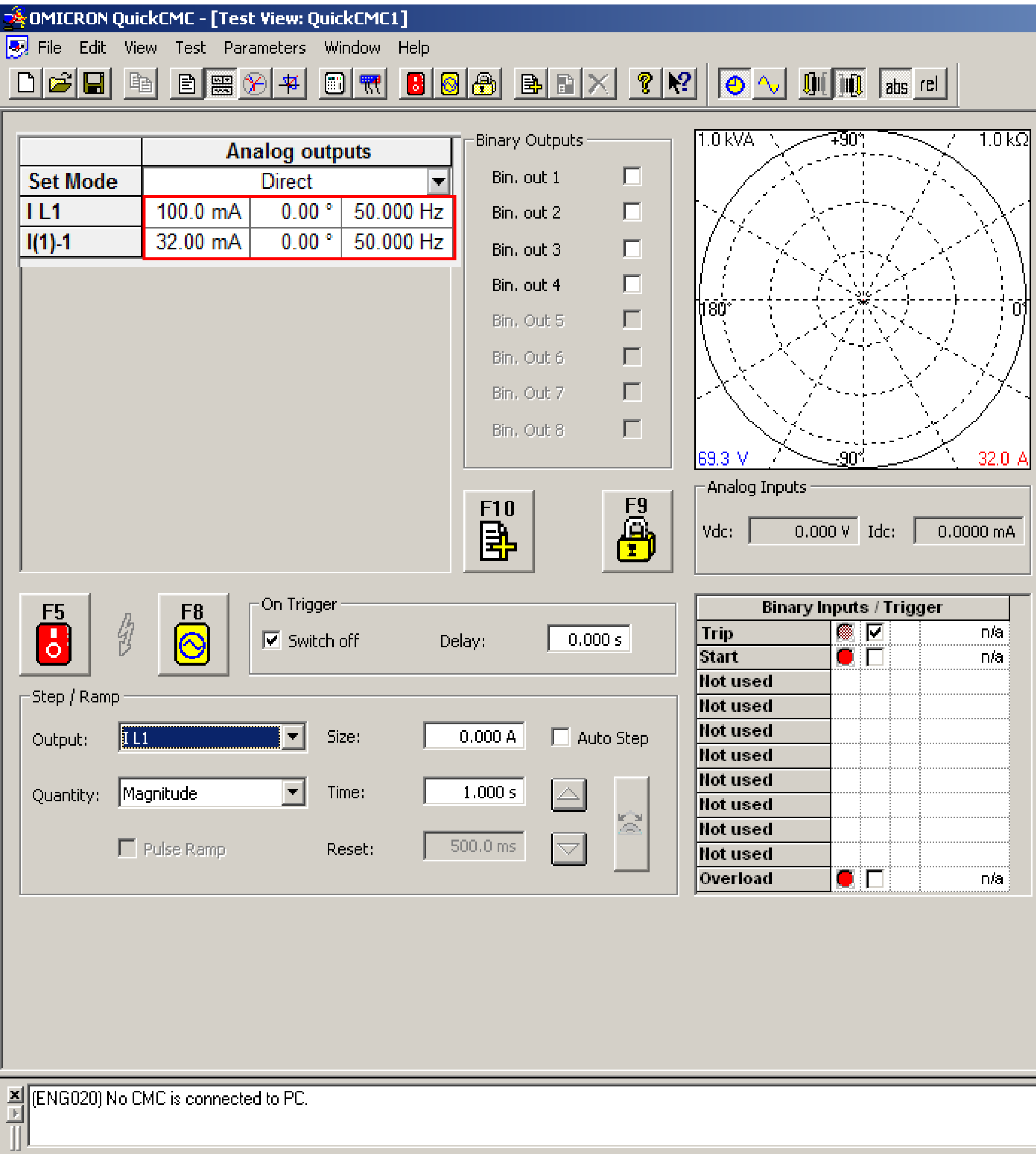
➢ Select Analog Outputs tab and select not used option for all the 3 voltages , IL2, IL3, I(2)-2 & I(3)-3.

➢ After finishing the selection select APPLY & OK for applying the settings

Using Omicron

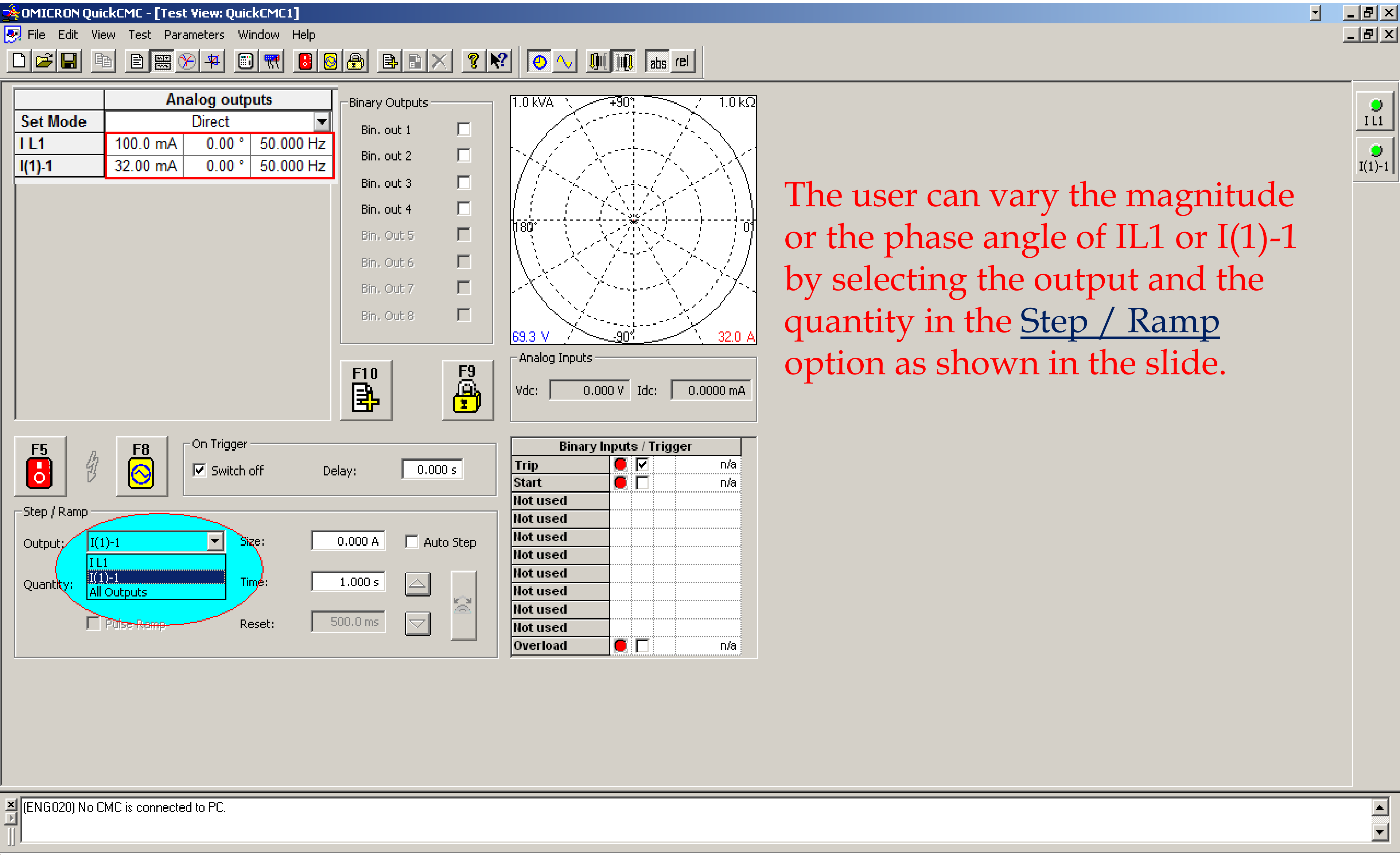


Using Omicron



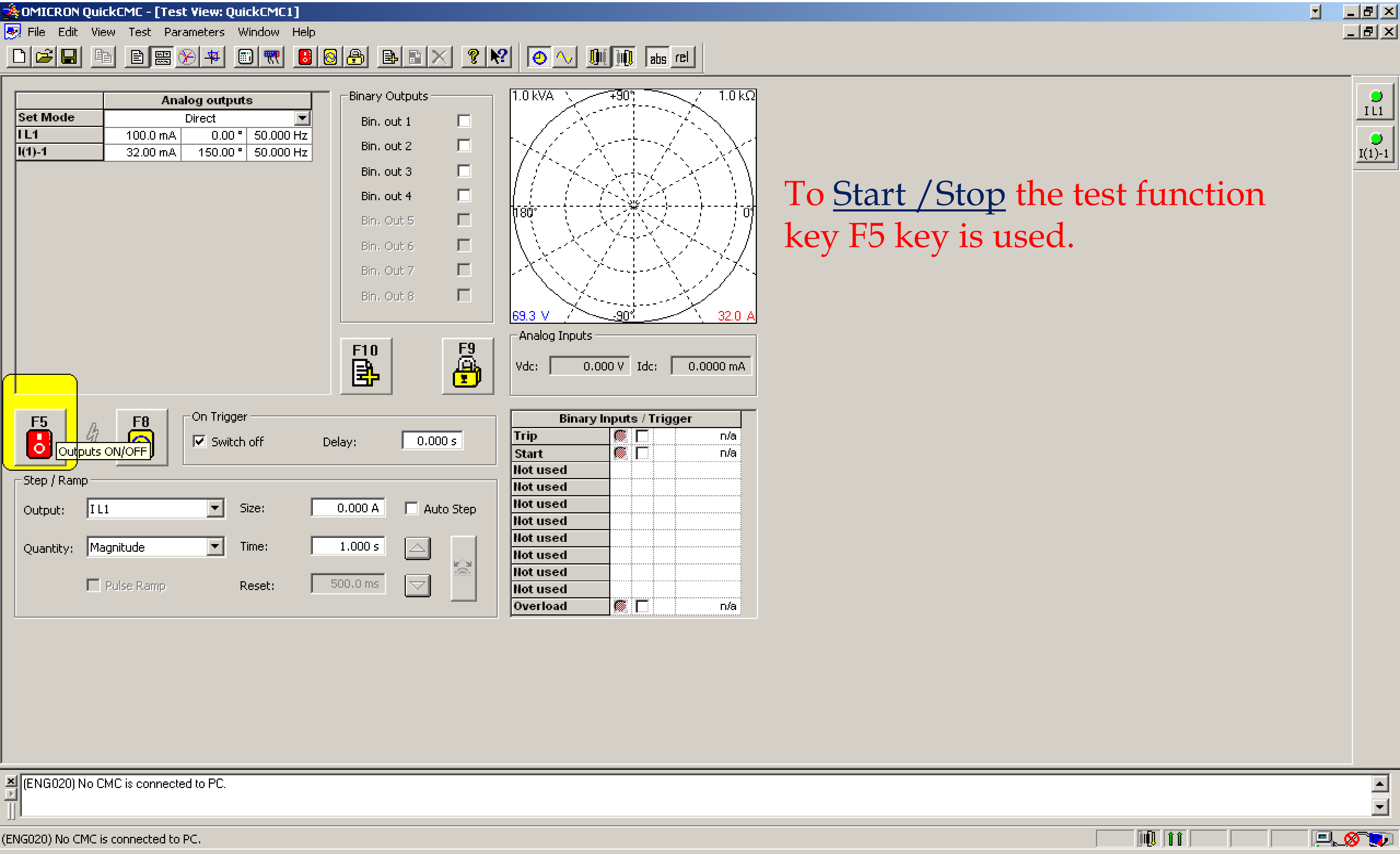
- Make sure that the frequency is set to 50Hz as the default value the omicron takes is 60Hz.
- The magnitude & phase angle is selected via the CT & vector group calculation

Using Omicron



The user can vary the magnitude or the phase angle of IL1 or I(1)-1 by selecting the output and the quantity in the Step / Ramp option as shown in the slide.

Using Omicron

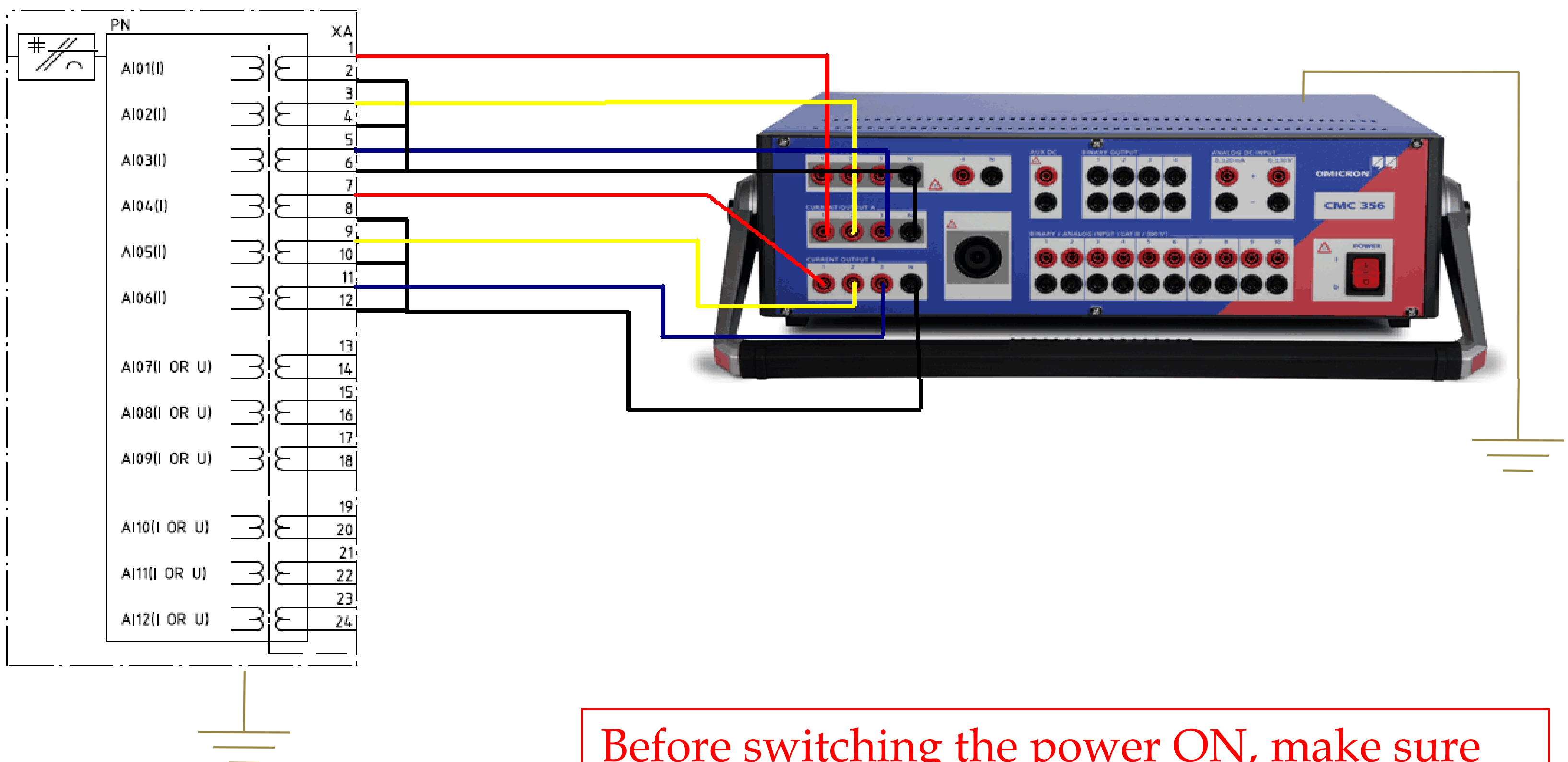


To Start / Stop the test function key F5 key is used.

RET 670

CT Connections between the IED and Omicron 356

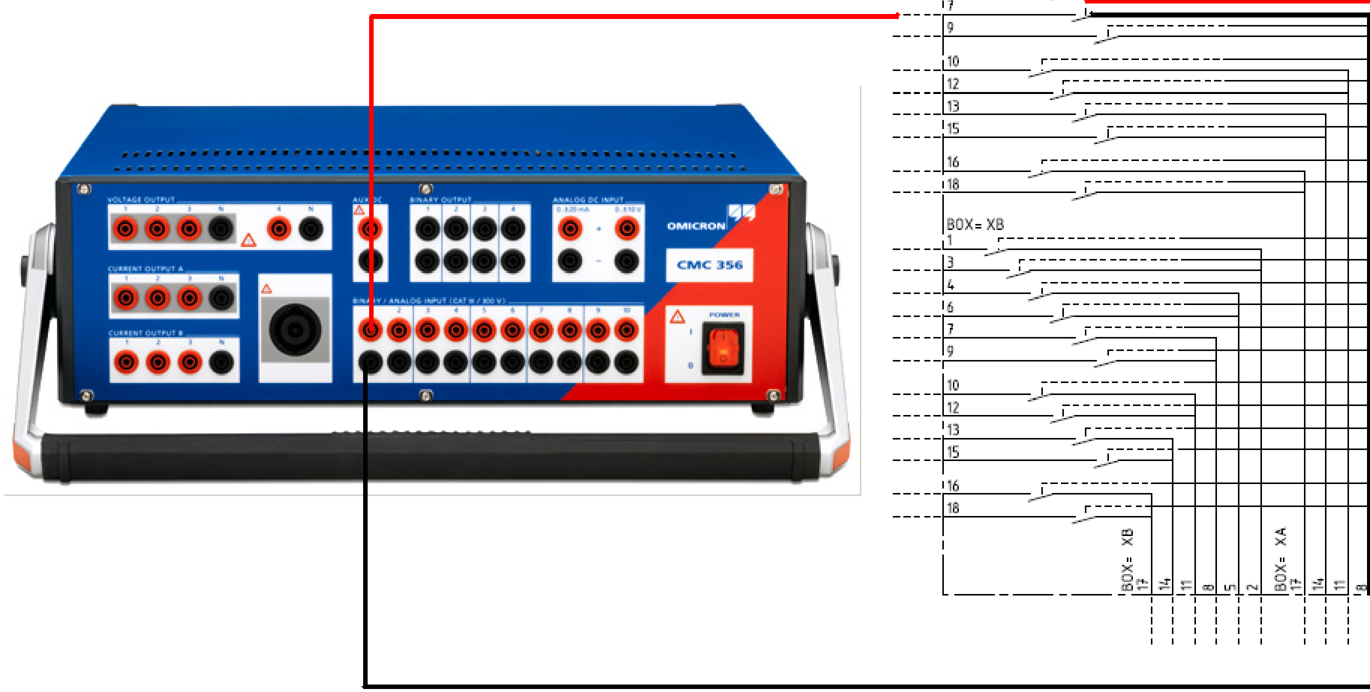
RET 670 IED **OMICRON 356**



Before switching the power ON, make sure that the IED & Omicron is earthed

Feedback from IED to Omicron

Connection for feedback from IED to Omicron



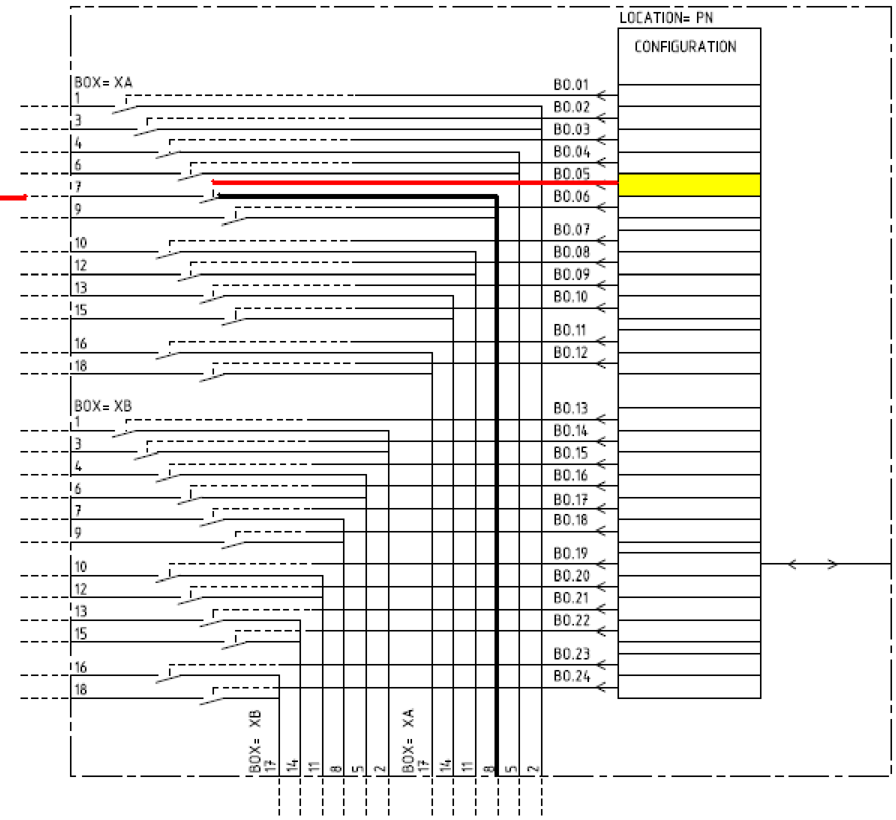
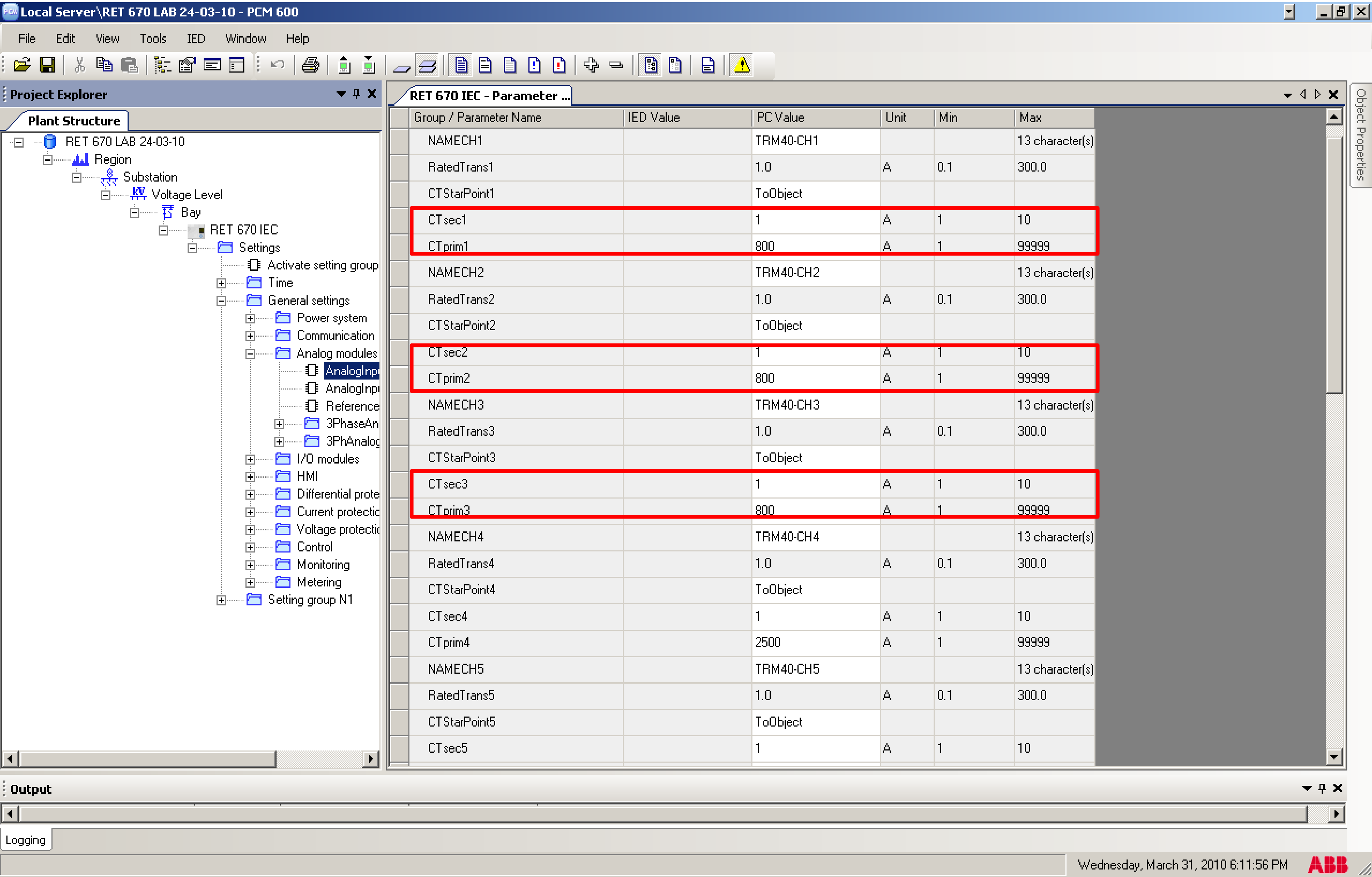


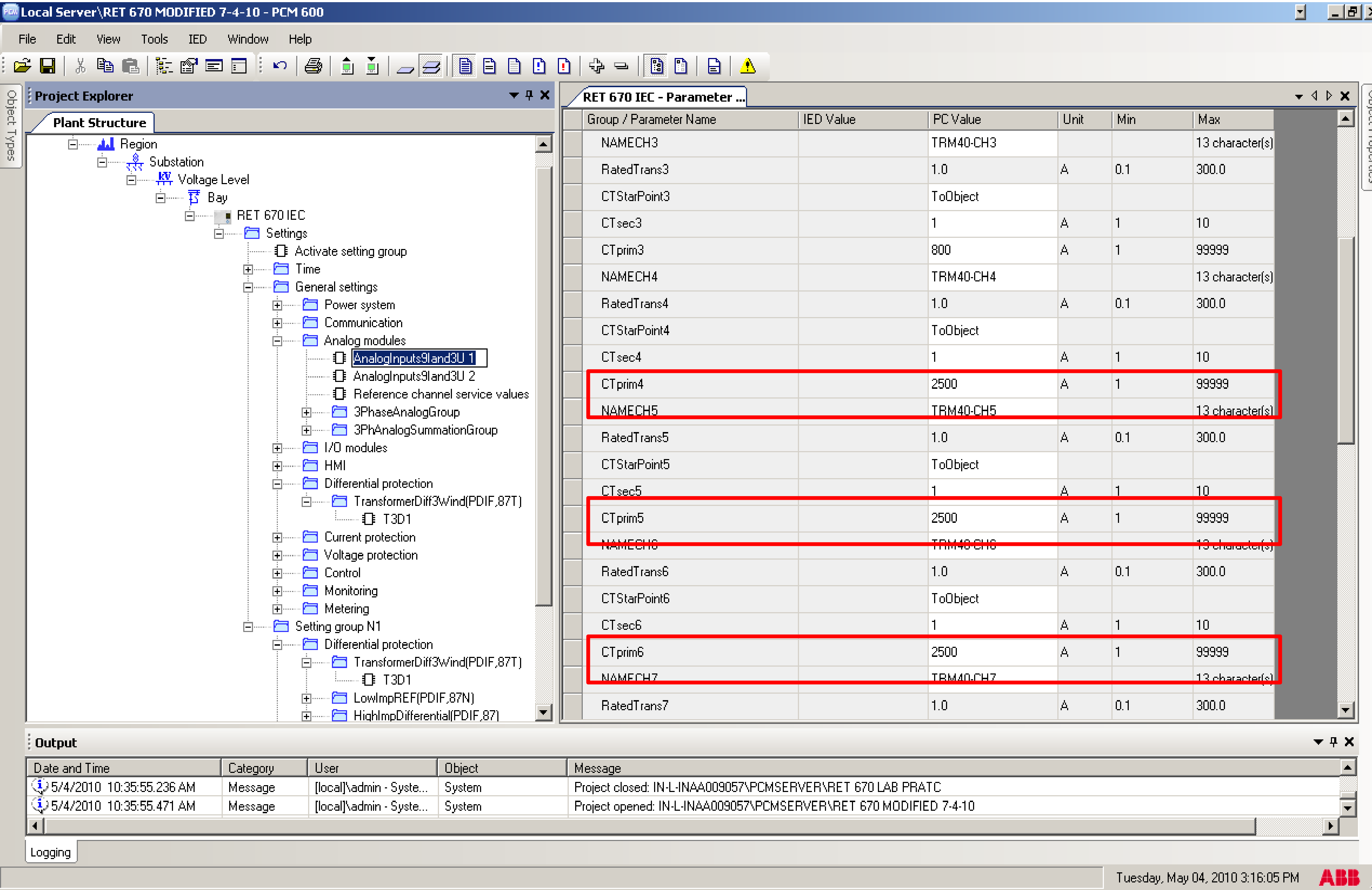
Figure 25: *Binary output module (BOM). Output contacts named XA corresponds to rear position X31, X41 etc. and output contacts named XB to rear position X32, X42, etc.*

RET 670 – CT RATIO

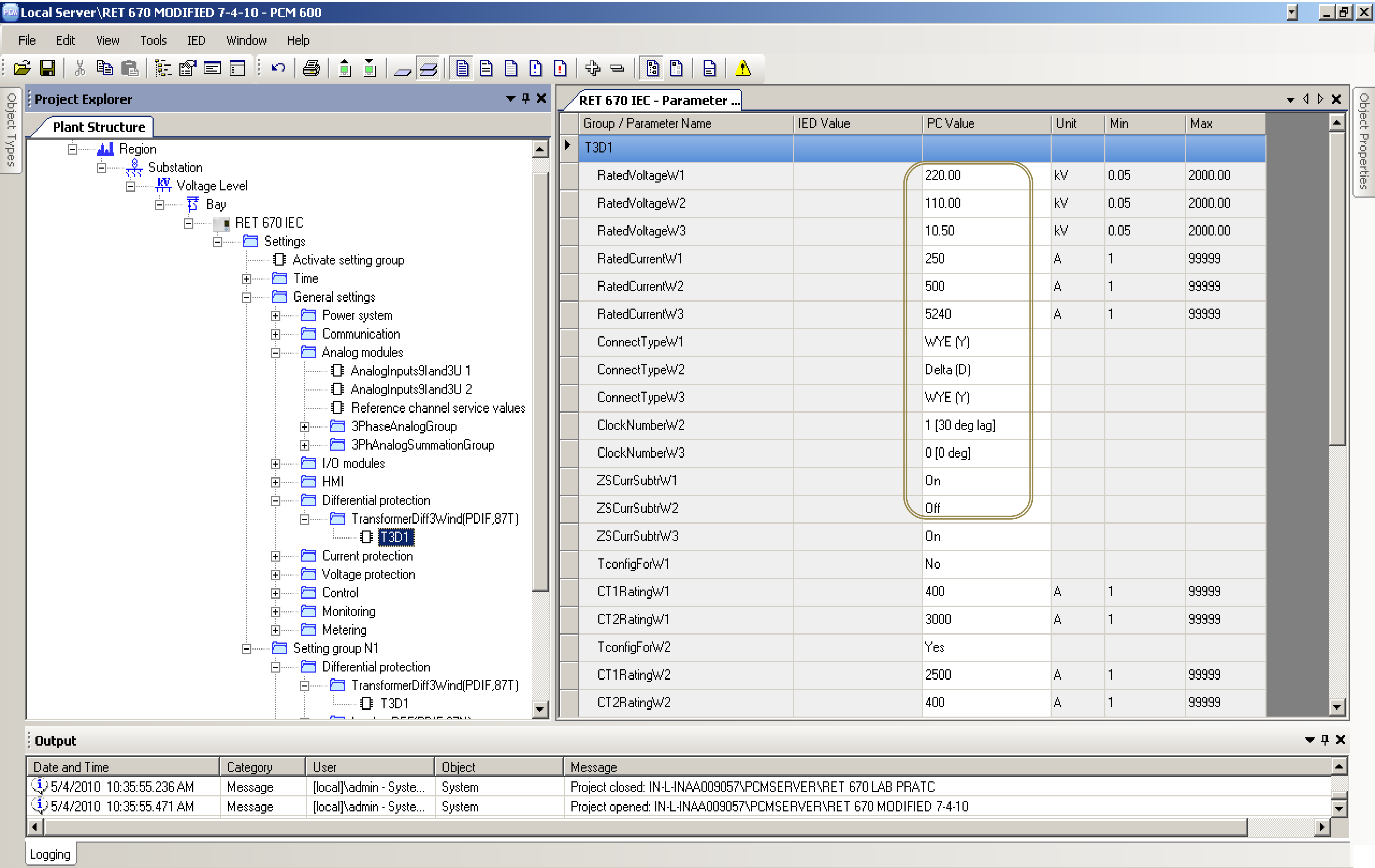


Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
NAMECH1		TRM40-CH1			13 character(s)
RatedTrans1		1.0	A	0.1	300.0
CTStarPoint1		ToObject			
CTsec1		1	A	1	10
CTprim1		800	A	1	99999
NAMECH2		TRM40-CH2			13 character(s)
RatedTrans2		1.0	A	0.1	300.0
CTStarPoint2		ToObject			
CTsec2		1	A	1	10
CTprim2		800	A	1	99999
NAMECH3		TRM40-CH3			13 character(s)
RatedTrans3		1.0	A	0.1	300.0
CTStarPoint3		ToObject			
CTsec3		1	A	1	10
CTprim3		800	A	1	99999
NAMECH4		TRM40-CH4			13 character(s)
RatedTrans4		1.0	A	0.1	300.0
CTStarPoint4		ToObject			
CTsec4		1	A	1	10
CTprim4		2500	A	1	99999
NAMECH5		TRM40-CH5			13 character(s)
RatedTrans5		1.0	A	0.1	300.0
CTStarPoint5		ToObject			
CTsec5		1	A	1	10

RET 670 – CT RATIO



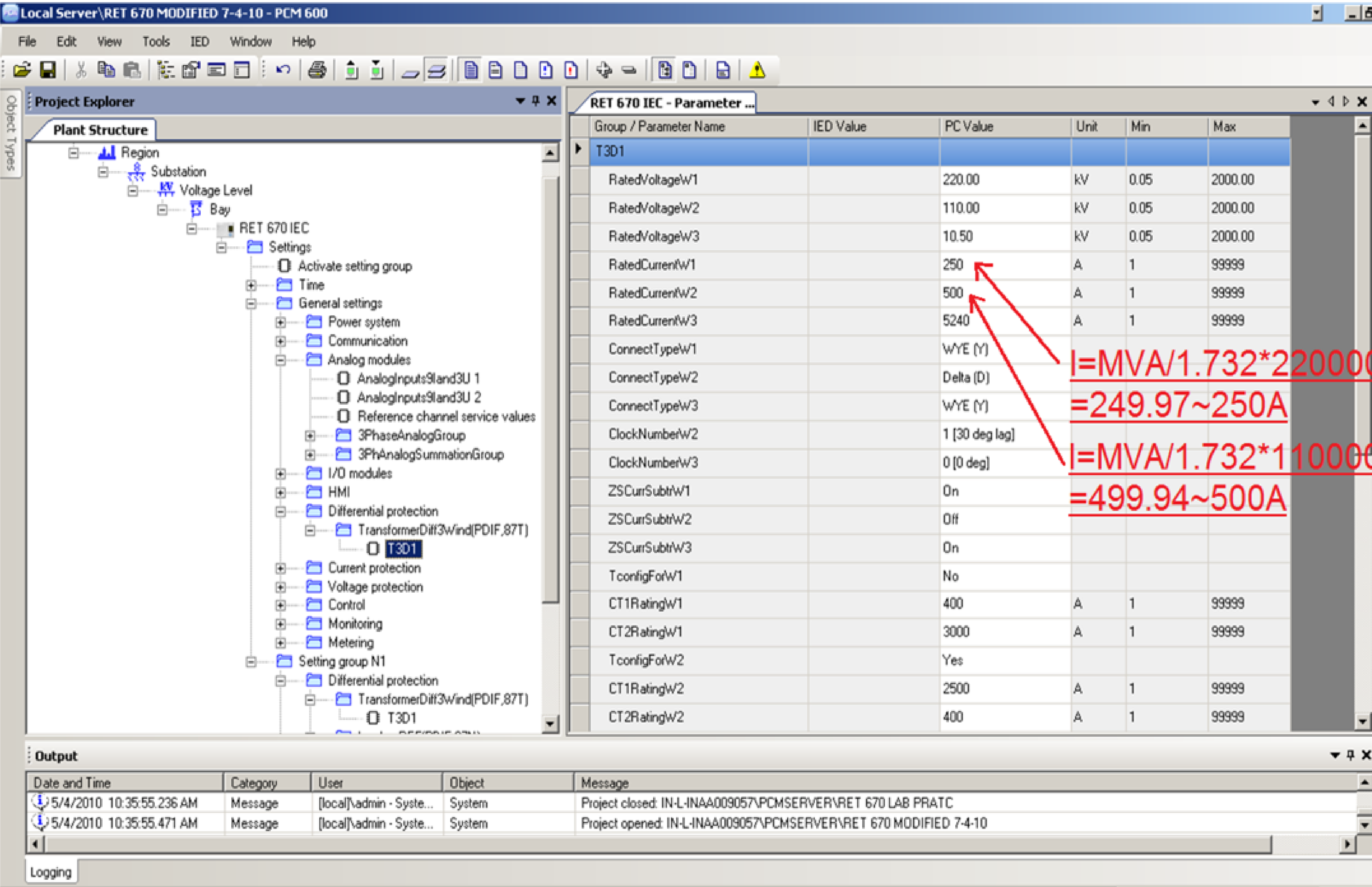
Relay parameter settings



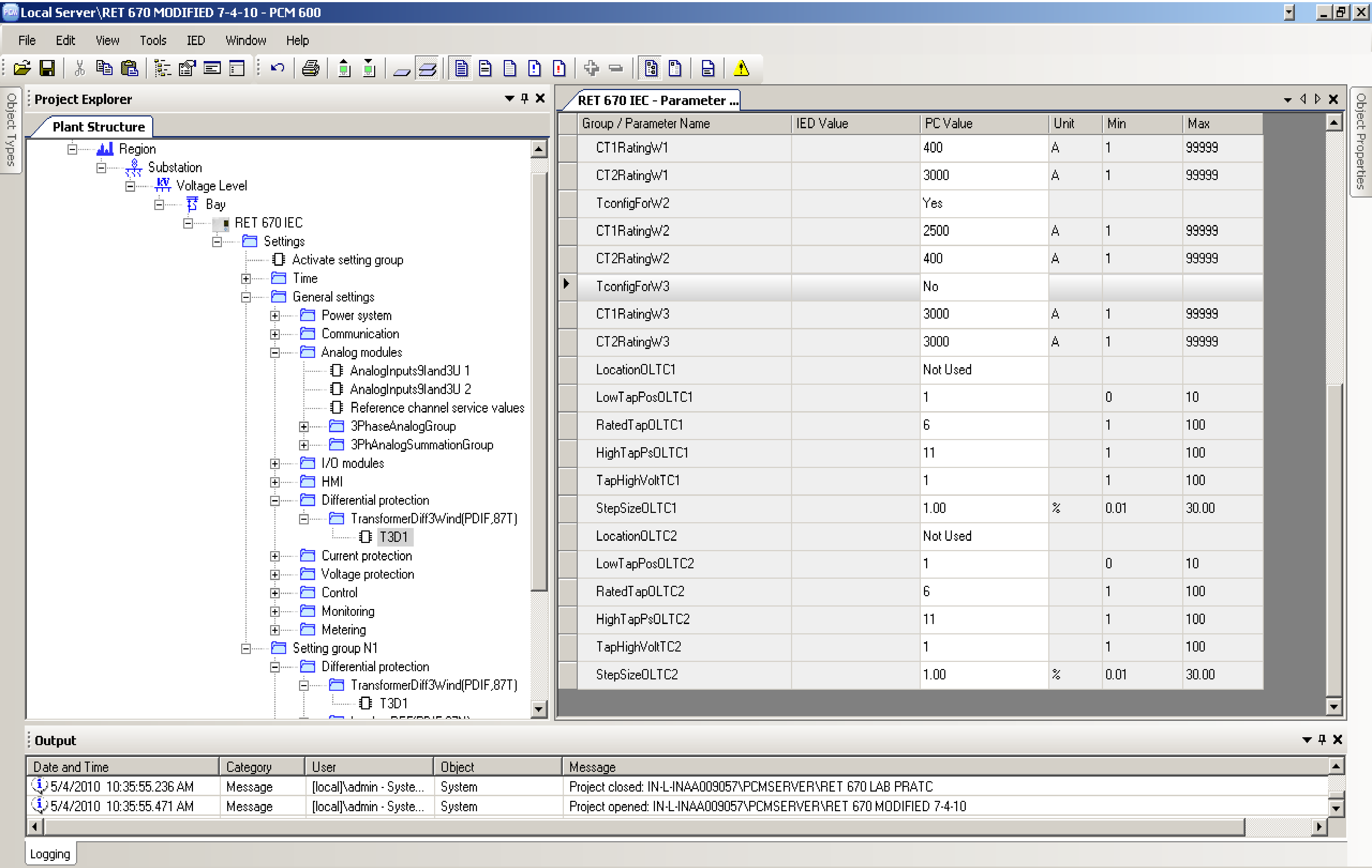
Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
T3D1					
RatedVoltageW1		220.00	kV	0.05	2000.00
RatedVoltageW2		110.00	kV	0.05	2000.00
RatedVoltageW3		10.50	kV	0.05	2000.00
RatedCurrentW1		250	A	1	99999
RatedCurrentW2		500	A	1	99999
RatedCurrentW3		5240	A	1	99999
ConnectTypeW1		WYE (Y)			
ConnectTypeW2		Delta (D)			
ConnectTypeW3		WYE (Y)			
ClockNumberW2		1 [30 deg lag]			
ClockNumberW3		0 [0 deg]			
ZSCurrSubtrW1		On			
ZSCurrSubtrW2		Off			
ZSCurrSubtrW3		On			
TconfigForW1		No			
CT1RatingW1		400	A	1	99999
CT2RatingW1		3000	A	1	99999
TconfigForW2		Yes			
CT1RatingW2		2500	A	1	99999
CT2RatingW2		400	A	1	99999

Date and Time	Category	User	Object	Message
5/4/2010 10:35:55.236 AM	Message	[local]\admin - Syste...	System	Project closed: IN-L-INAA009057\PCMSERVER\RET 670 LAB PRATC
5/4/2010 10:35:55.471 AM	Message	[local]\admin - Syste...	System	Project opened: IN-L-INAA009057\PCMSERVER\RET 670 MODIFIED 7-4-10

Relay parameter settings



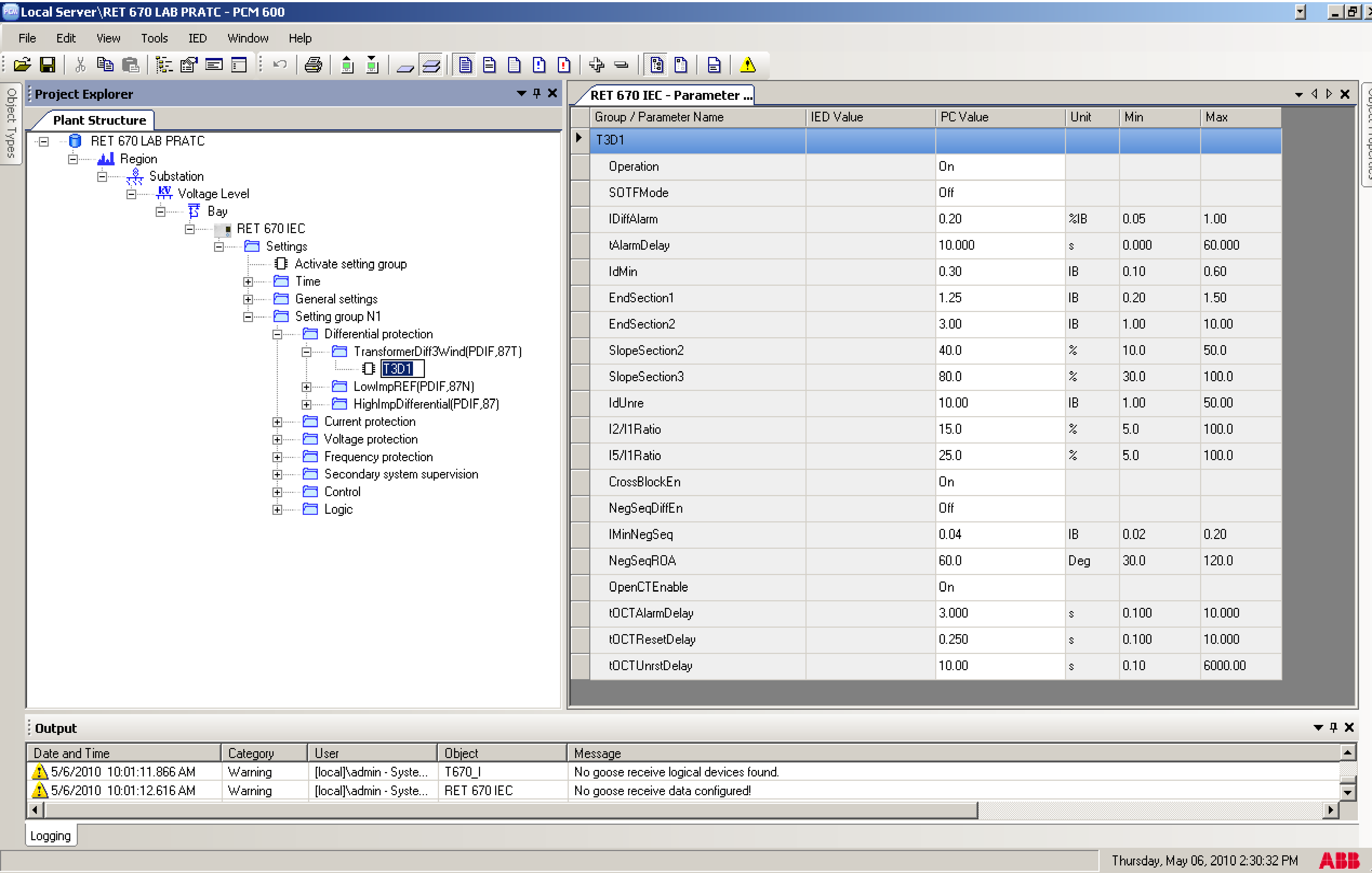
Relay parameter settings



Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
CT1RatingW1		400	A	1	99999
CT2RatingW1		3000	A	1	99999
TconfigForW2		Yes			
CT1RatingW2		2500	A	1	99999
CT2RatingW2		400	A	1	99999
TconfigForW3		No			
CT1RatingW3		3000	A	1	99999
CT2RatingW3		3000	A	1	99999
LocationOLTC1		Not Used			
LowTapPosOLTC1		1		0	10
RatedTapOLTC1		6		1	100
HighTapPsOLTC1		11		1	100
TapHighVoltTC1		1		1	100
StepSizeOLTC1		1.00	%	0.01	30.00
LocationOLTC2		Not Used			
LowTapPosOLTC2		1		0	10
RatedTapOLTC2		6		1	100
HighTapPsOLTC2		11		1	100
TapHighVoltTC2		1		1	100
StepSizeOLTC2		1.00	%	0.01	30.00

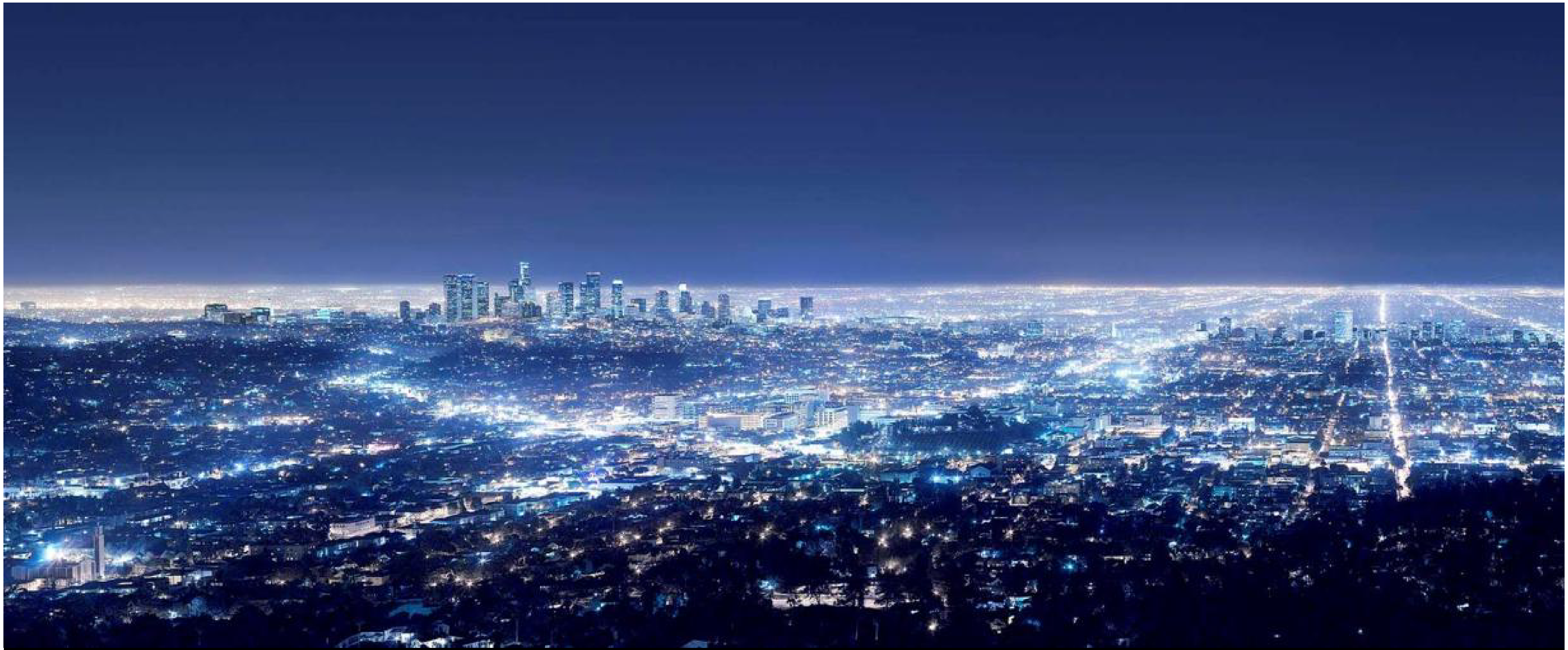
Date and Time	Category	User	Object	Message
5/4/2010 10:35:55.236 AM	Message	[local]\admin - Syste...	System	Project closed: IN-L-INAA009057\PCMSERVER\RET 670 LAB PRATC
5/4/2010 10:35:55.471 AM	Message	[local]\admin - Syste...	System	Project opened: IN-L-INAA009057\PCMSERVER\RET 670 MODIFIED 7-4-10

Relay parameter settings



Group / Parameter Name	IED Value	PC Value	Unit	Min	Max
T3D1					
Operation		On			
SOTFMode		Off			
IDiffAlarm		0.20	%IB	0.05	1.00
tAlarmDelay		10.000	s	0.000	60.000
IdMin		0.30	IB	0.10	0.60
EndSection1		1.25	IB	0.20	1.50
EndSection2		3.00	IB	1.00	10.00
SlopeSection2		40.0	%	10.0	50.0
SlopeSection3		80.0	%	30.0	100.0
IdUnre		10.00	IB	1.00	50.00
I2/I1Ratio		15.0	%	5.0	100.0
I5/I1Ratio		25.0	%	5.0	100.0
CrossBlockEn		On			
NegSeqDiffEn		Off			
IMinNegSeq		0.04	IB	0.02	0.20
NegSeqROA		60.0	Deg	30.0	120.0
OpenCTEnable		On			
tOCTAlarmDelay		3.000	s	0.100	10.000
tOCTResetDelay		0.250	s	0.100	10.000
tOCTUnrstDelay		10.00	s	0.10	6000.00

Date and Time	Category	User	Object	Message
5/6/2010 10:01:11.866 AM	Warning	[local]\admin - Syste...	T670_I	No goose receive logical devices found.
5/6/2010 10:01:12.616 AM	Warning	[local]\admin - Syste...	RET 670 IEC	No goose receive data configured!



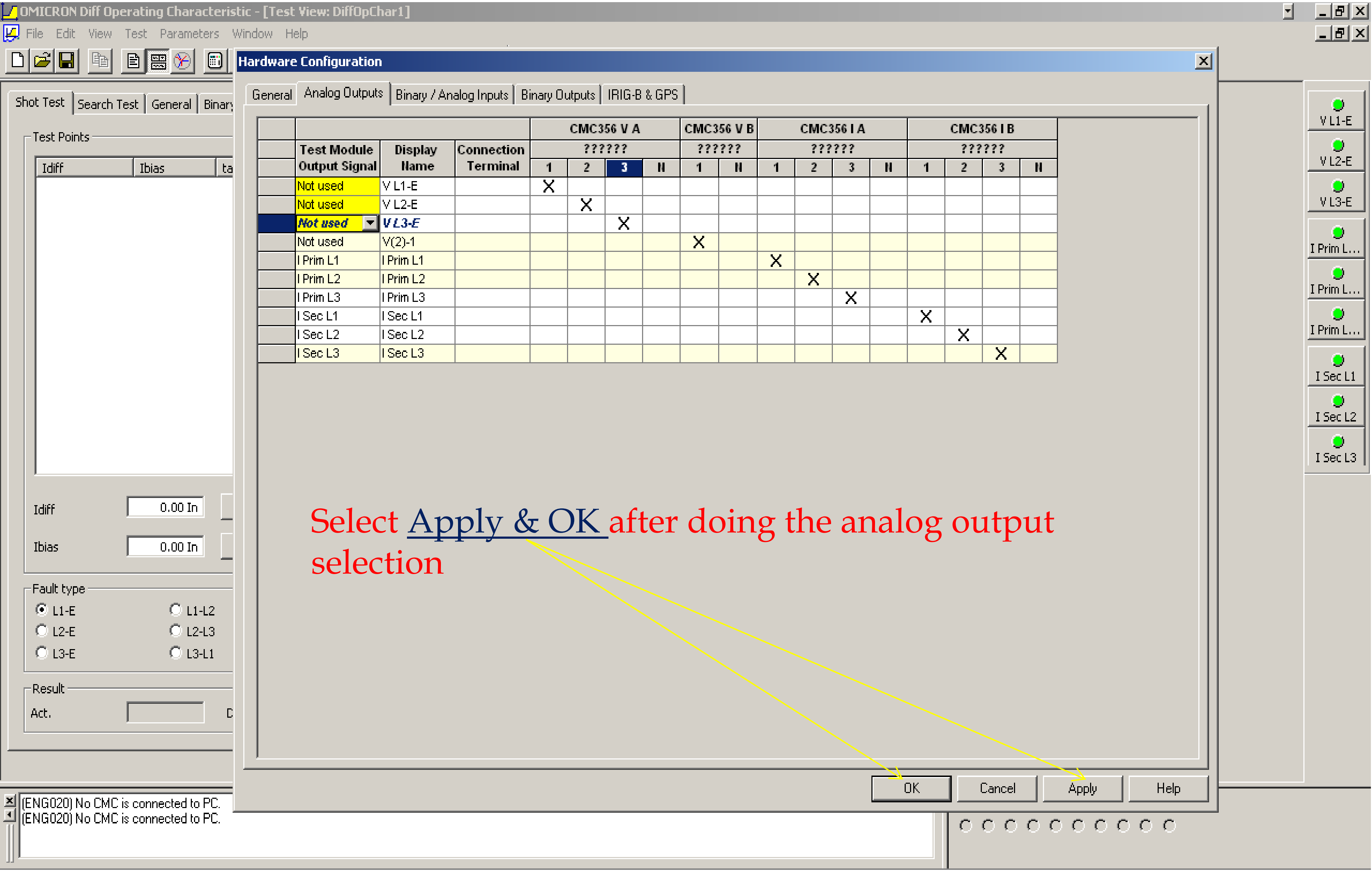
Antony RAJA, INOPC - 08/08/2013

RET 670

Differential slope setting in omicron

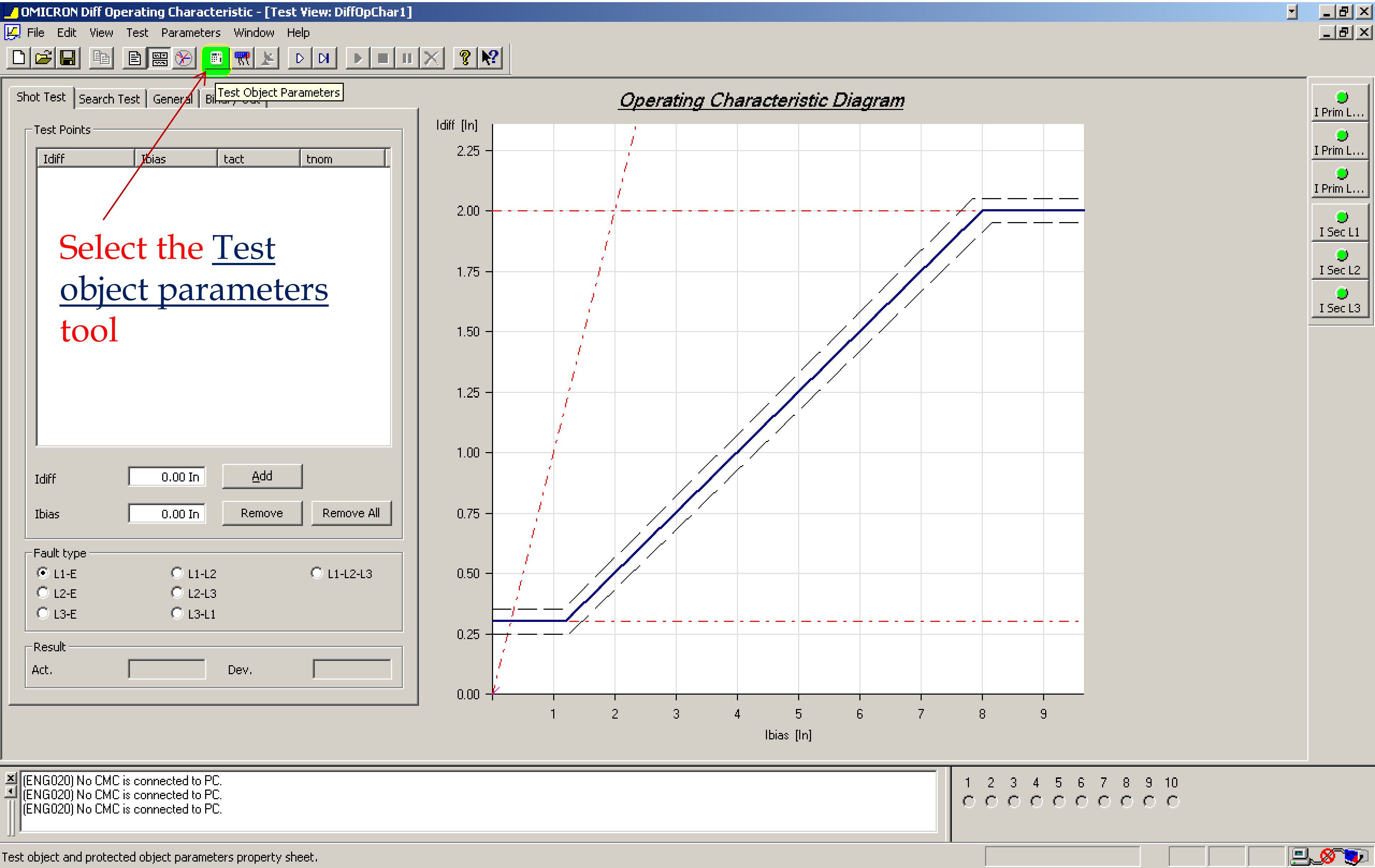
Differential Slope Setting

Differential Slope Setting

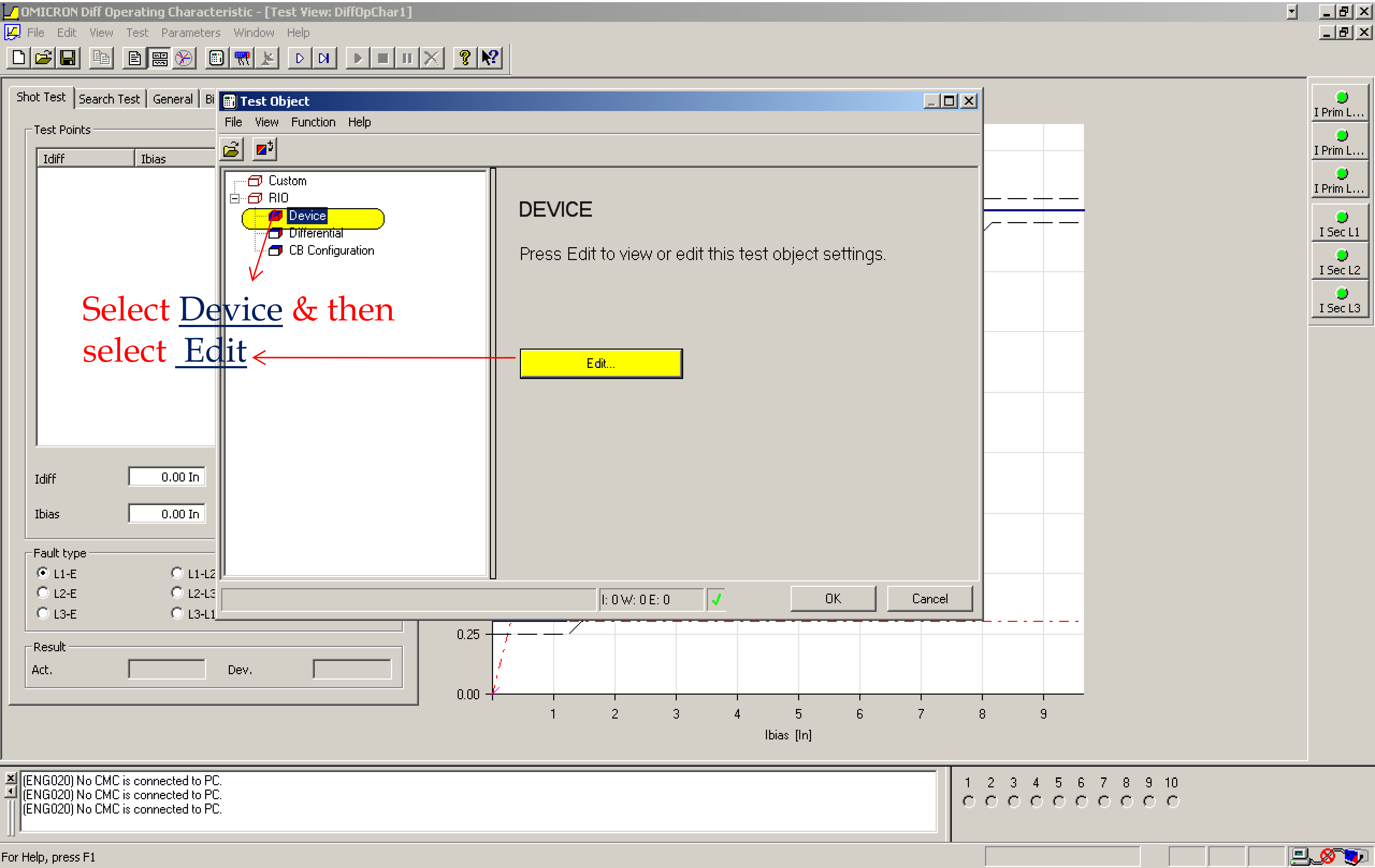


Select Apply & OK after doing the analog output selection

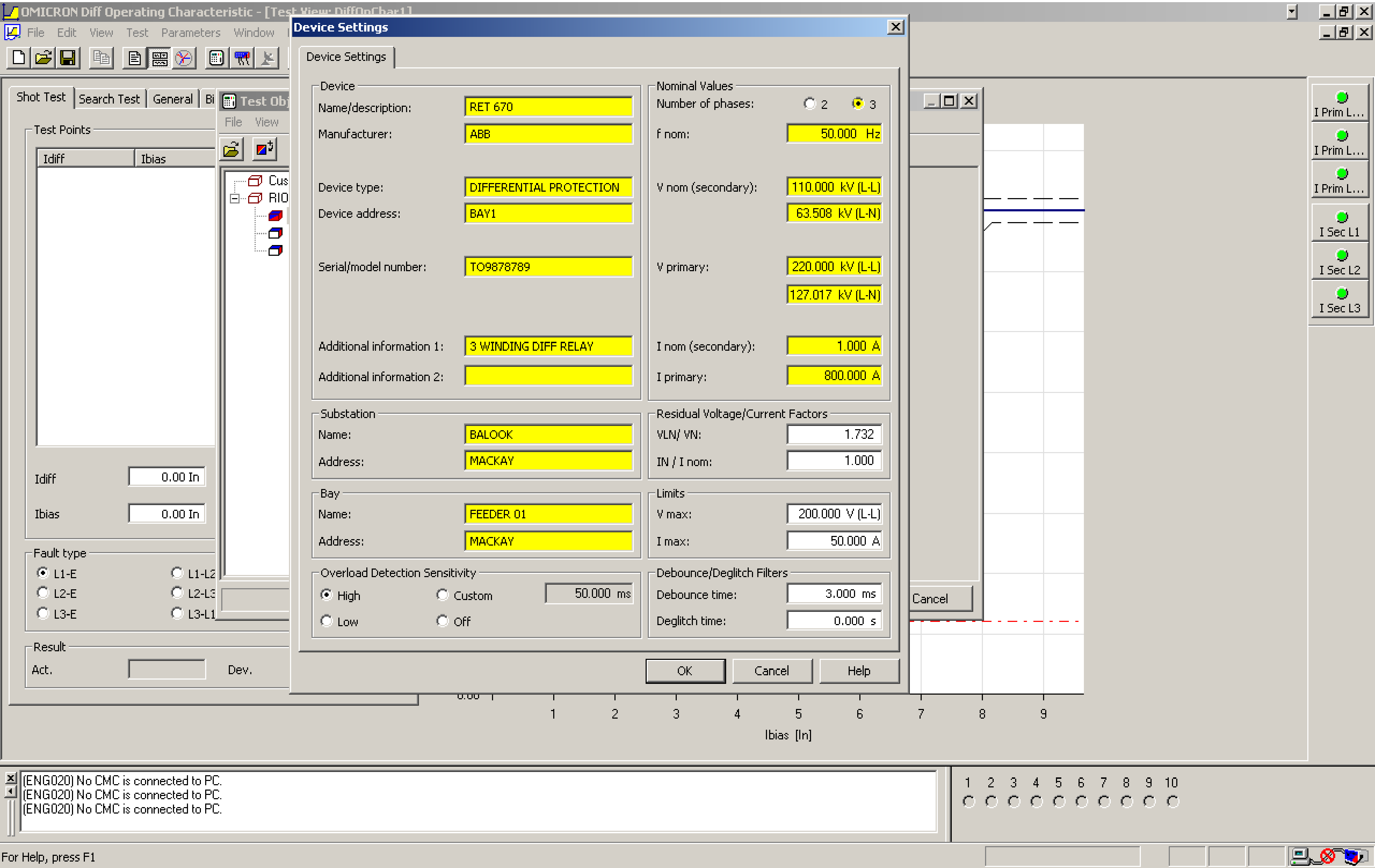
Differential Slope Setting



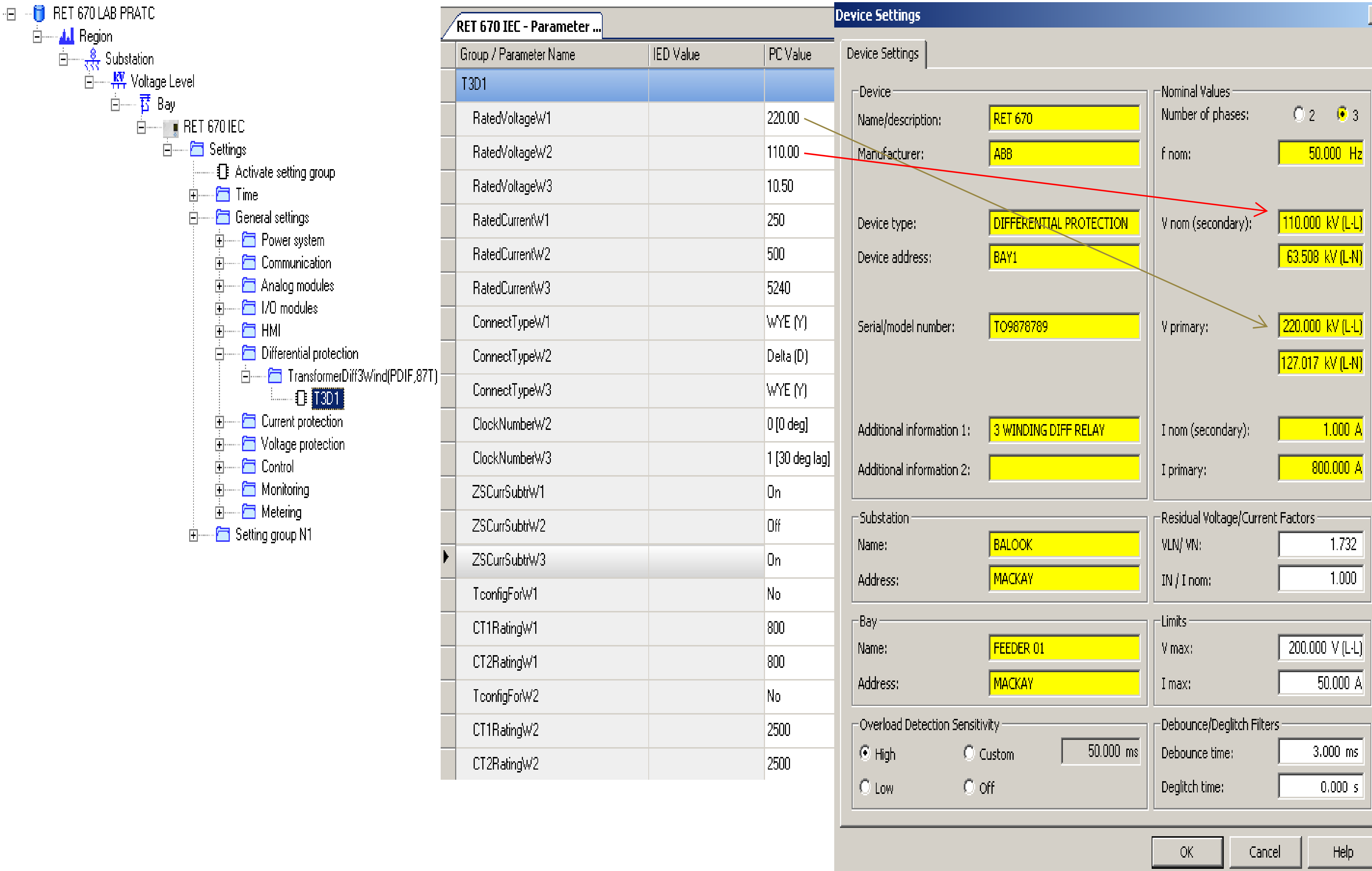
Differential Slope Setting



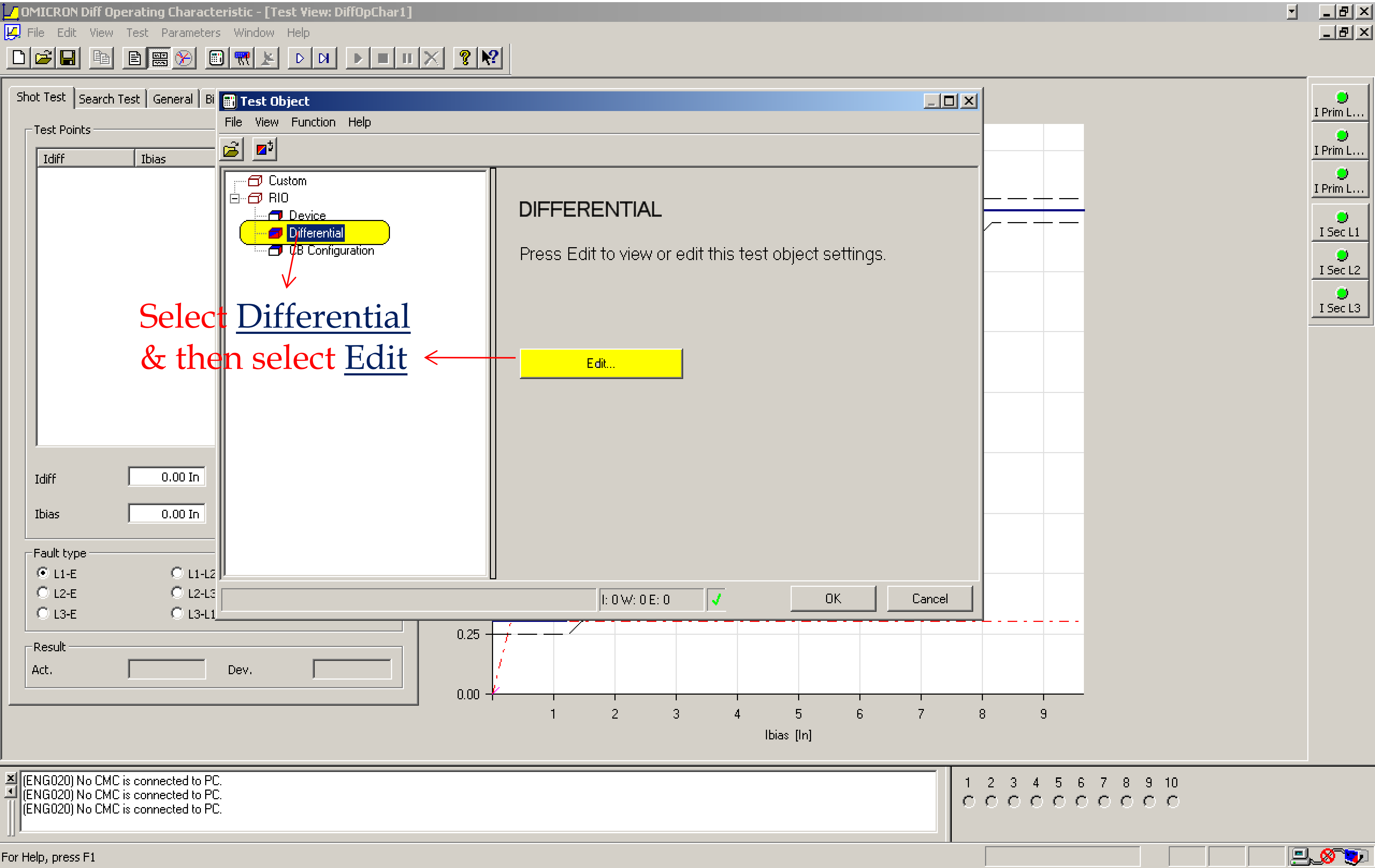
Differential Slope Setting



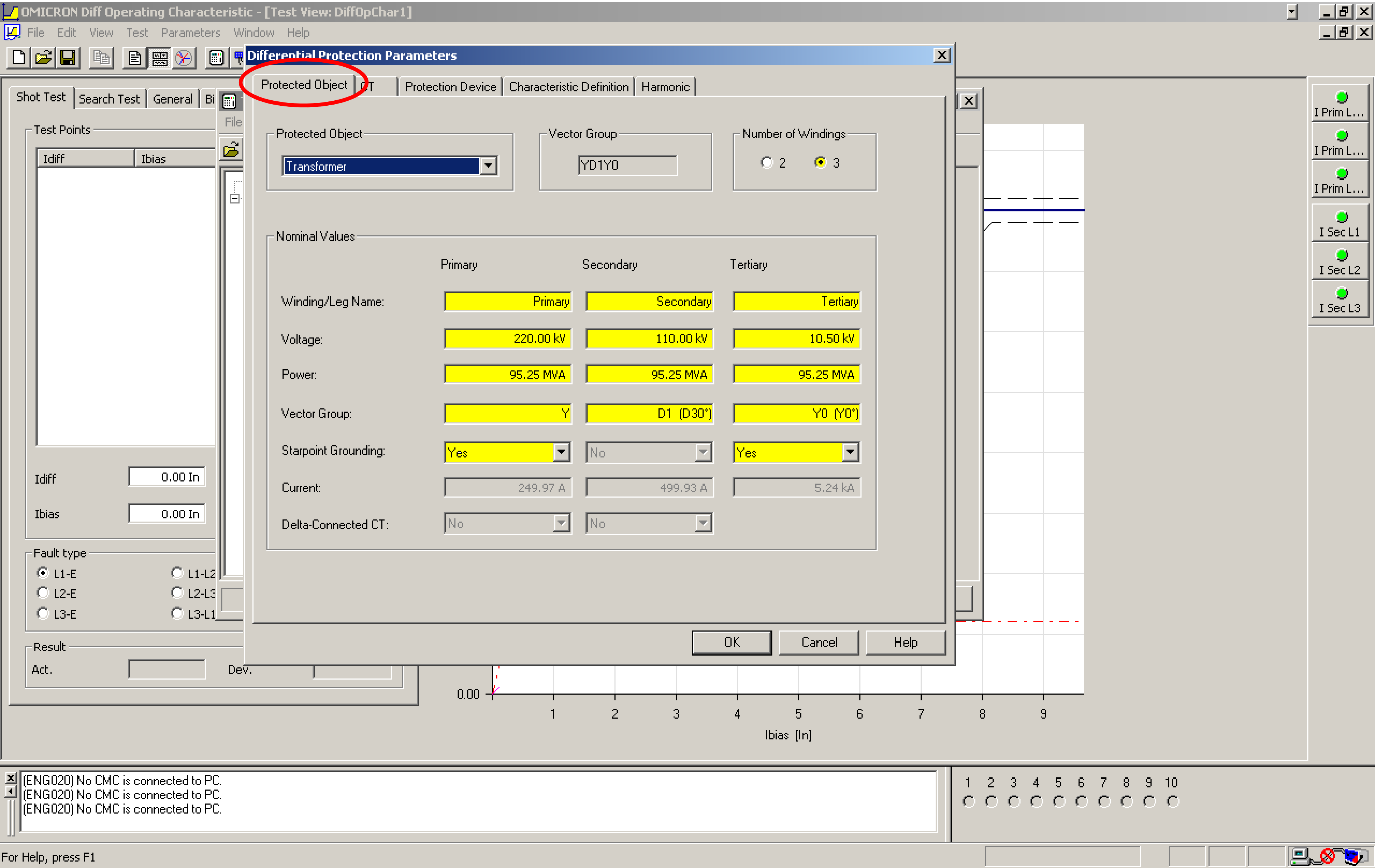
Differential Slope Setting



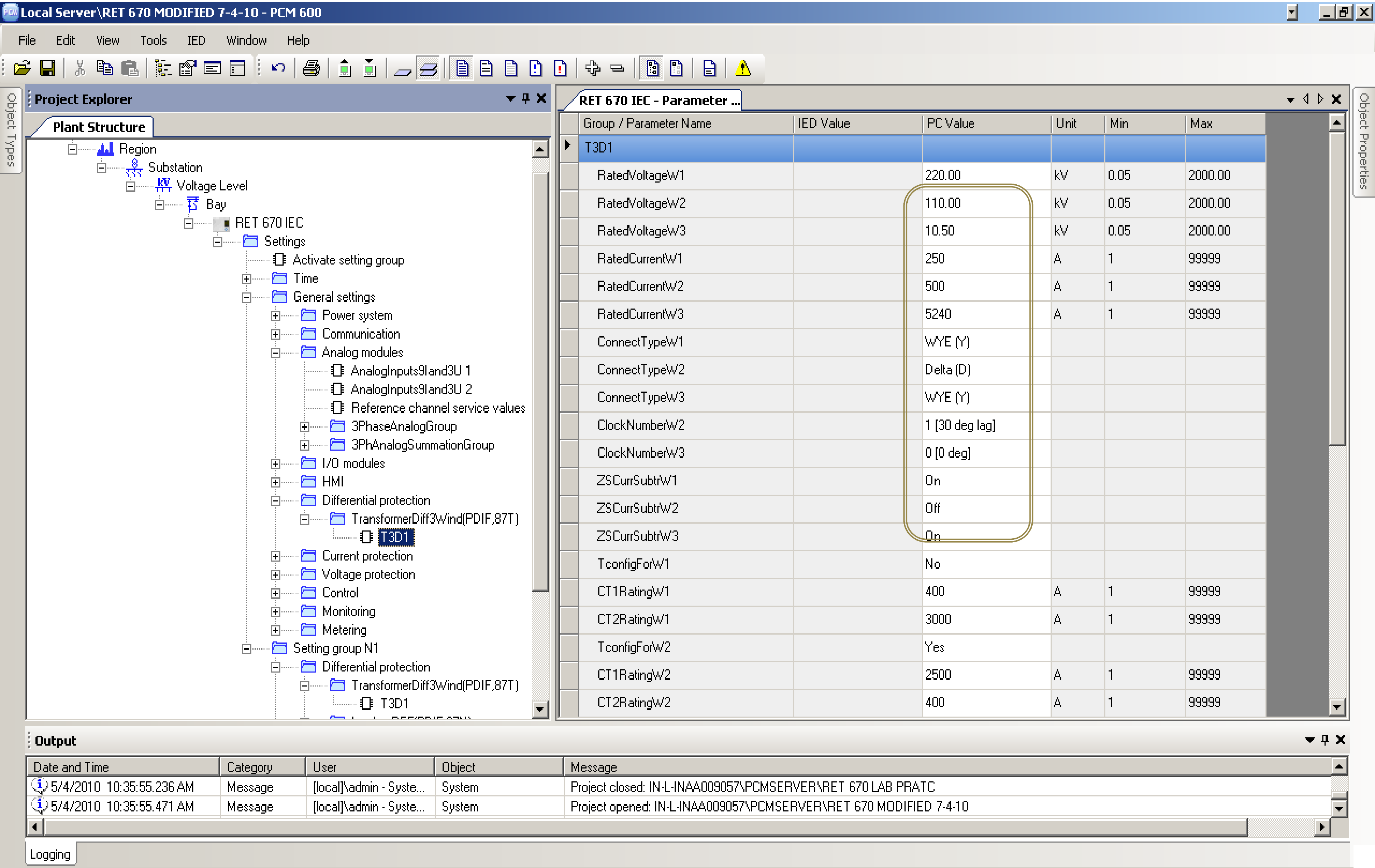
Differential Slope Setting



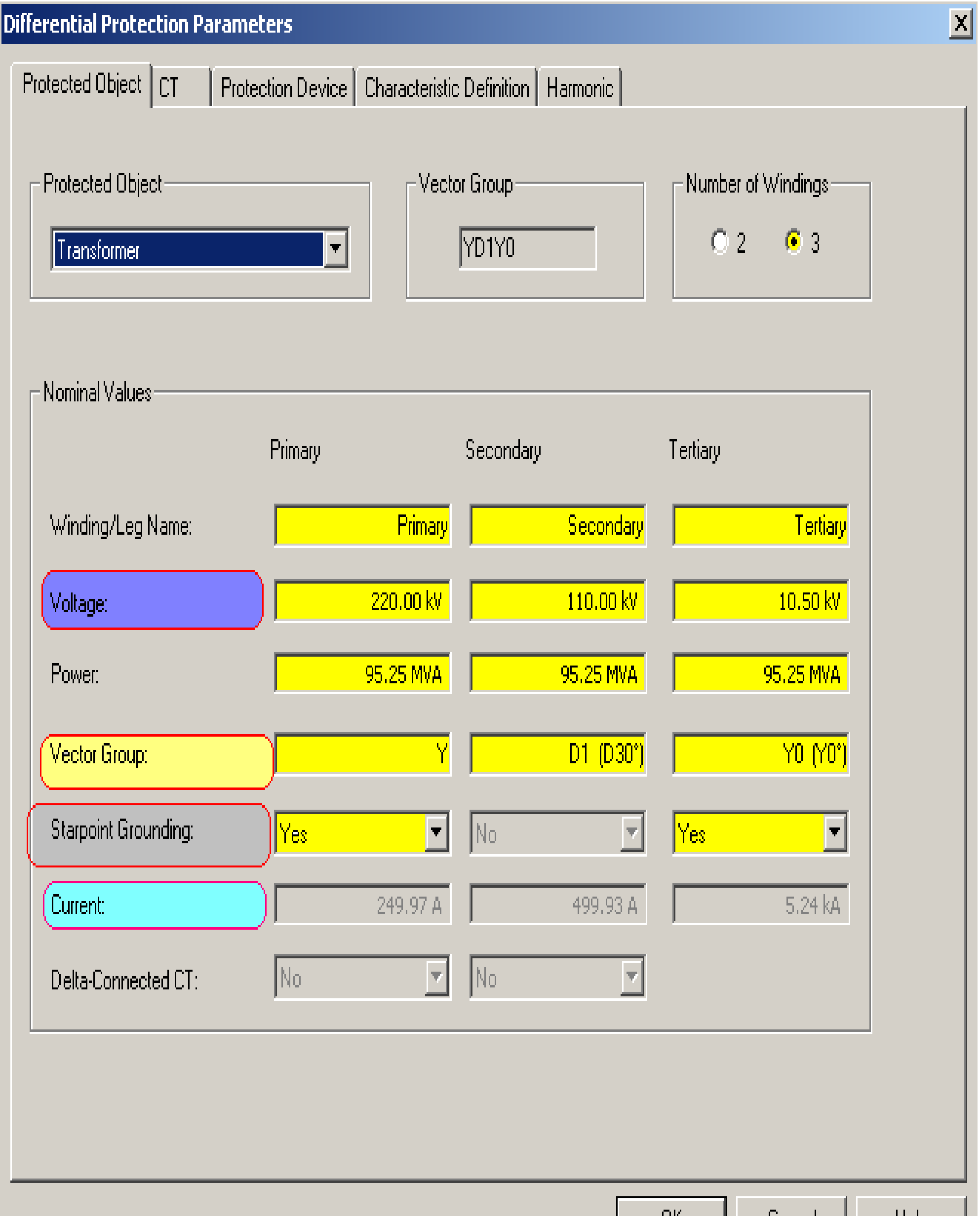
Differential Slope Setting

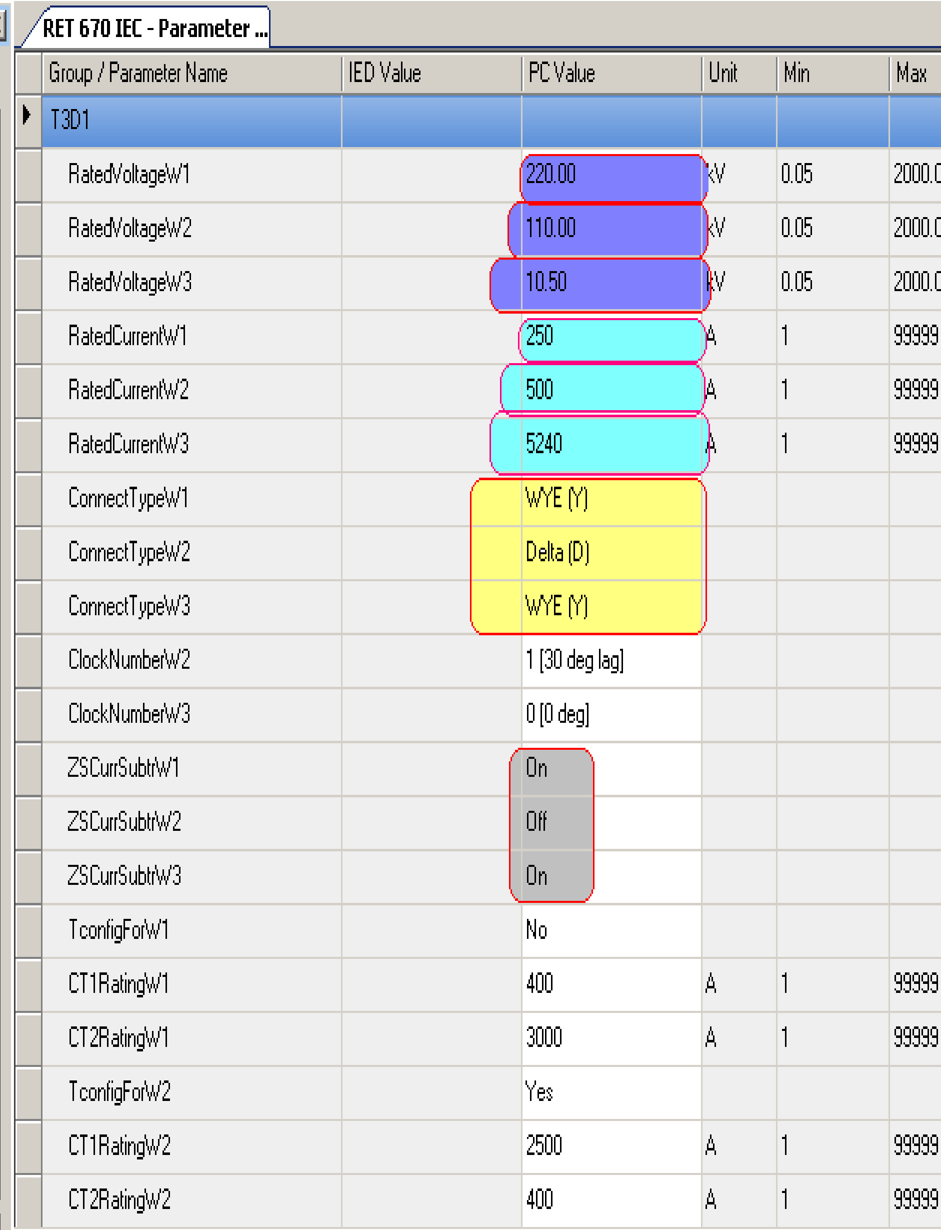


Relay parameter settings

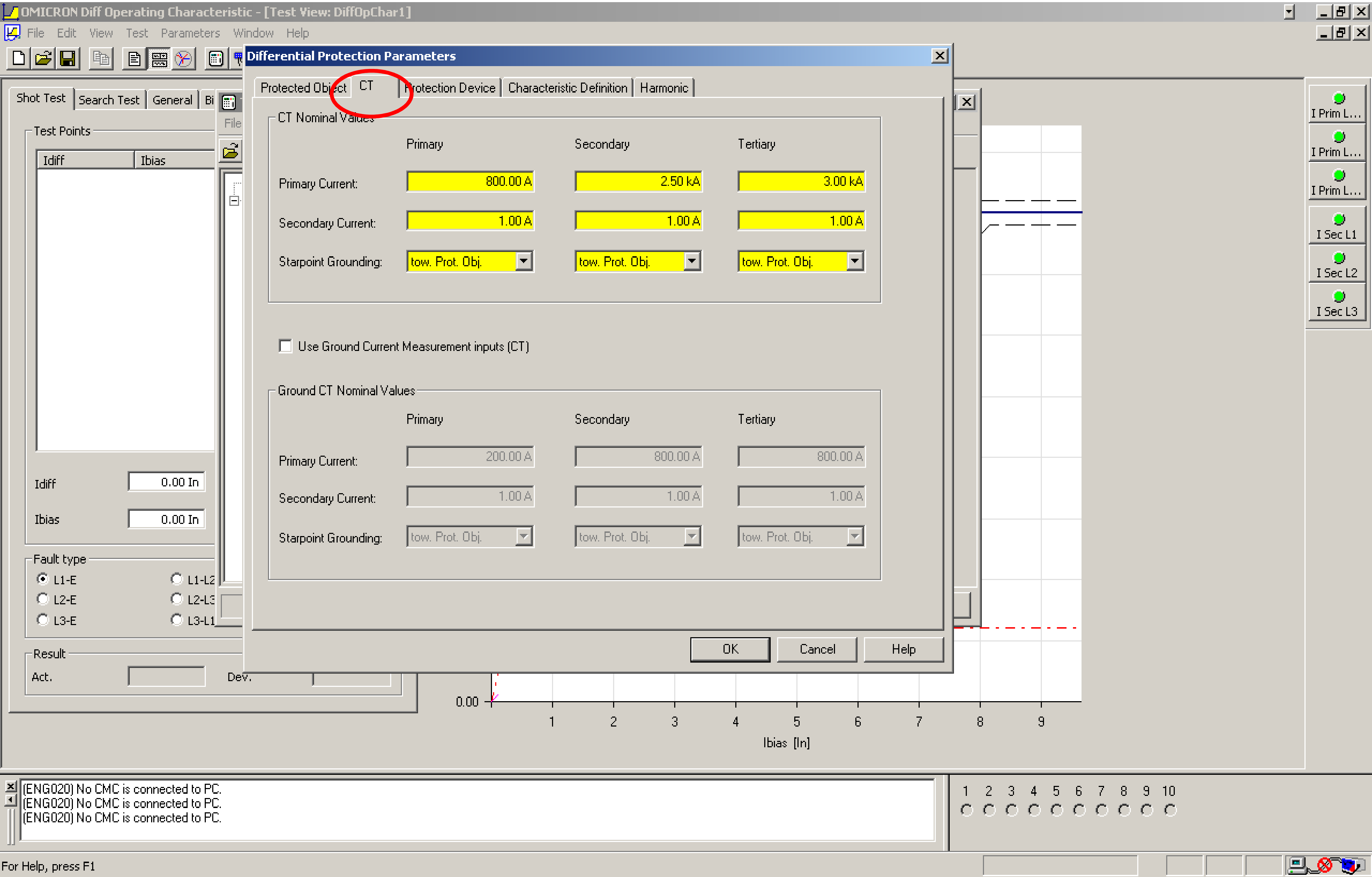


Differential Slope Setting

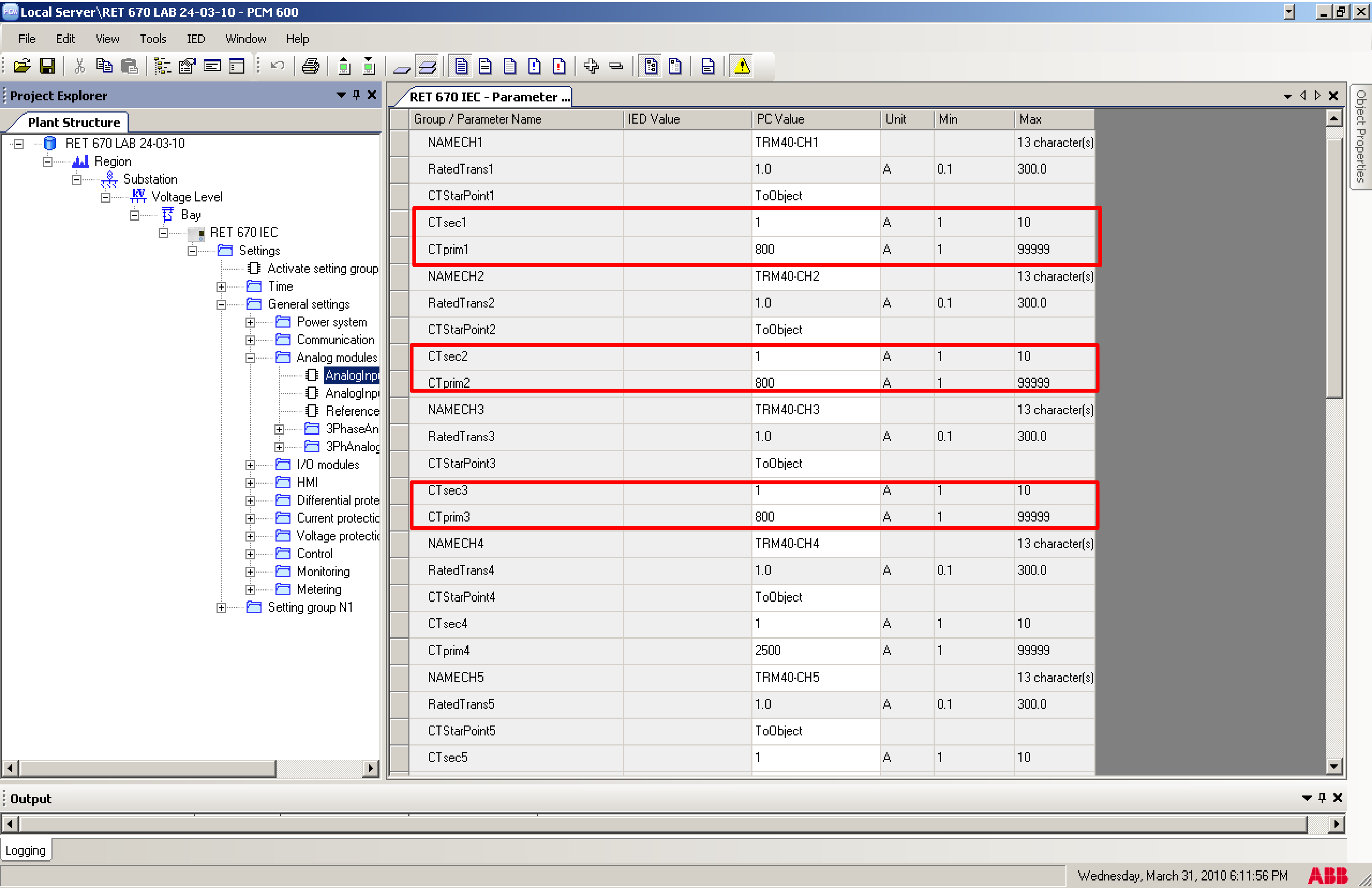




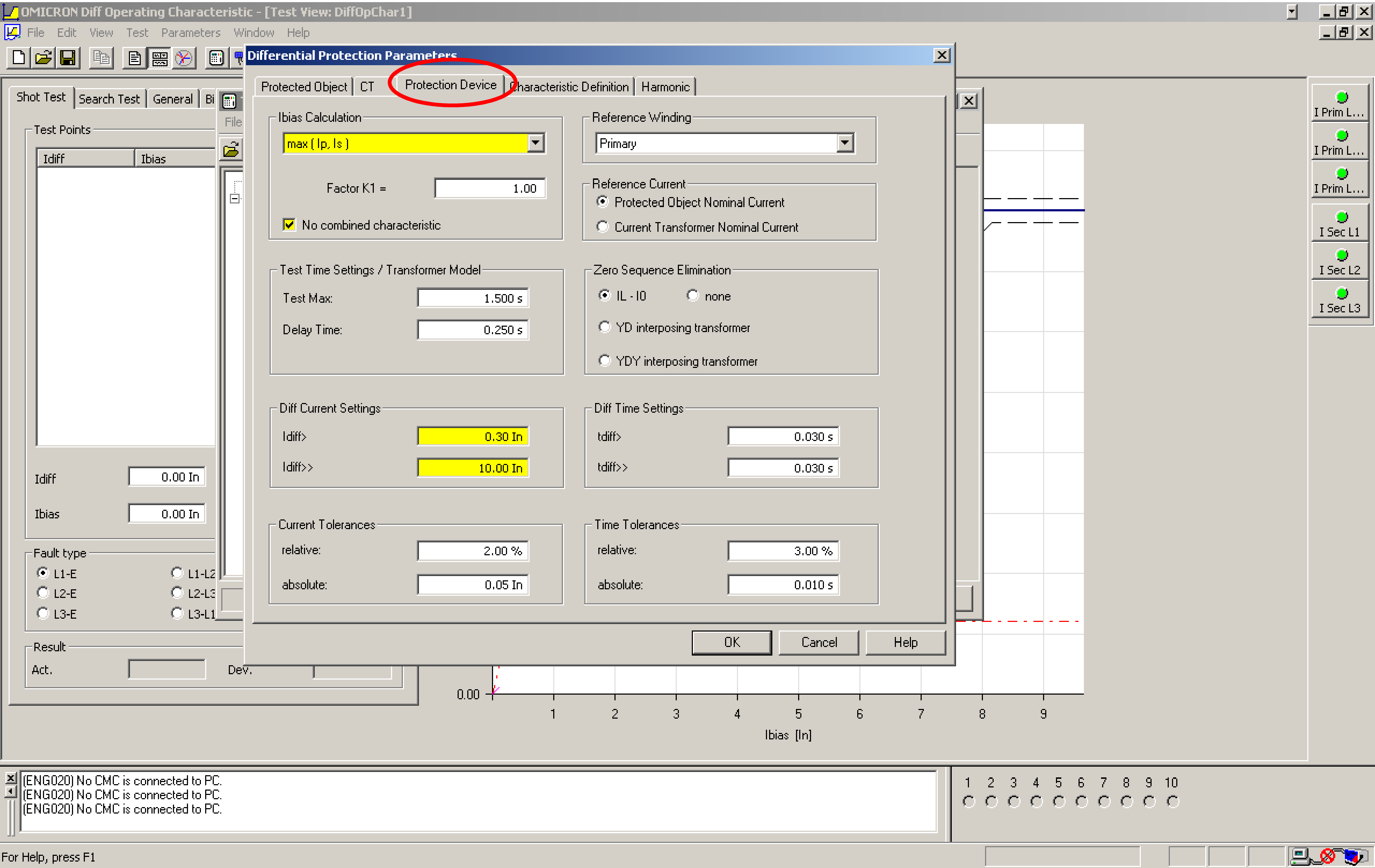
Differential Slope Testing



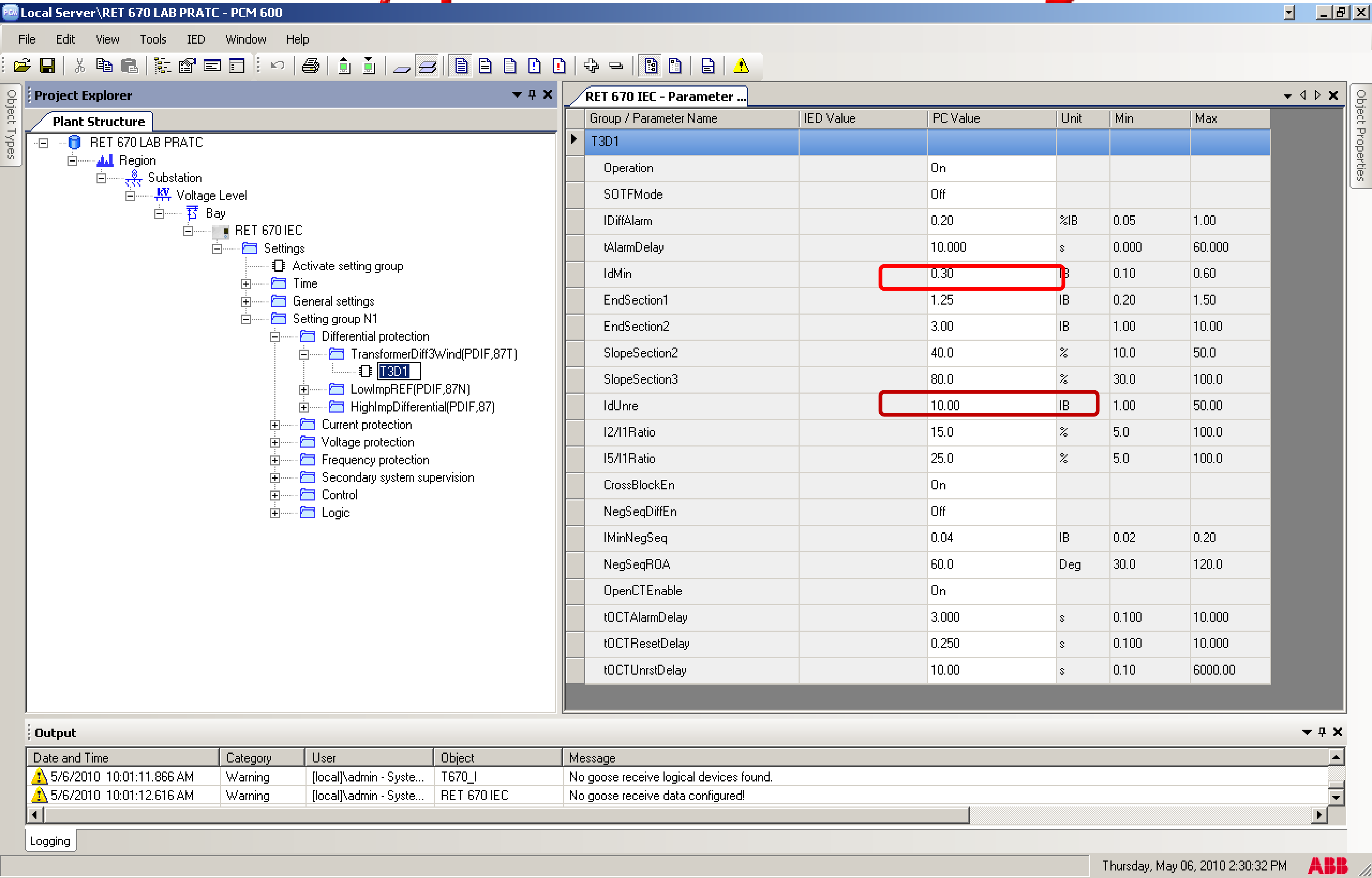
RET 670 – CT RATIO



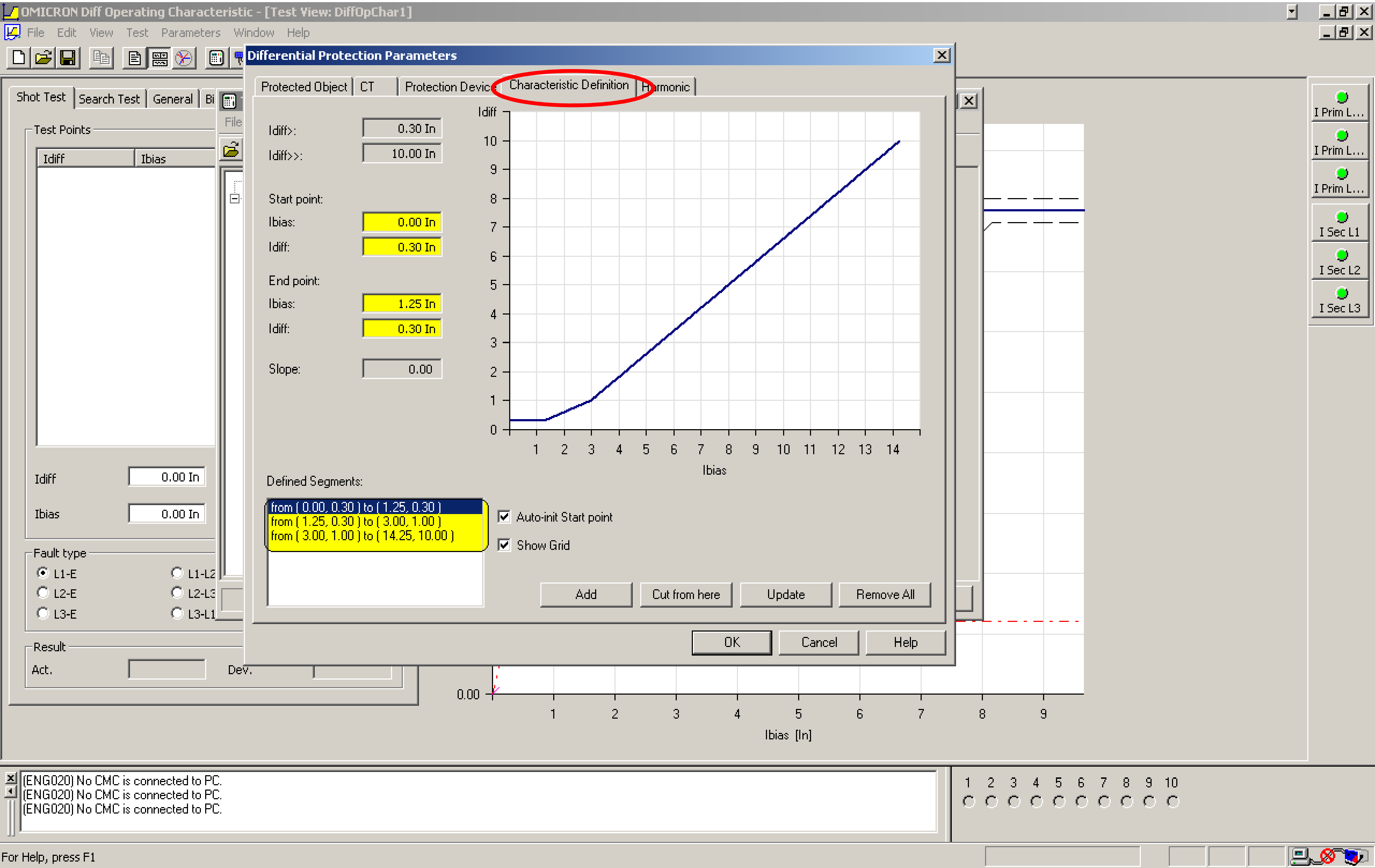
Differential Slope Setting



Relay parameter settings



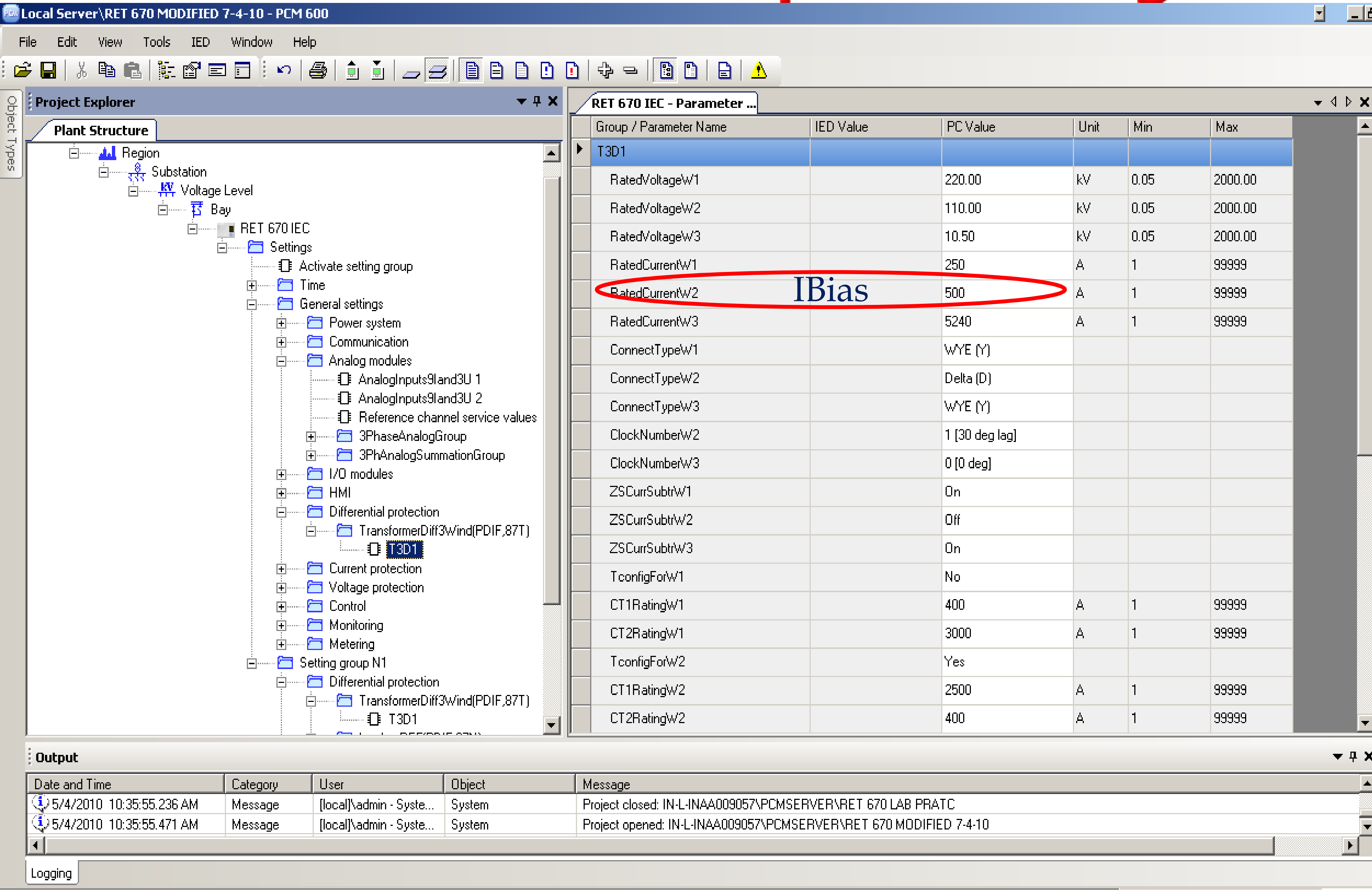
Differential Slope Setting



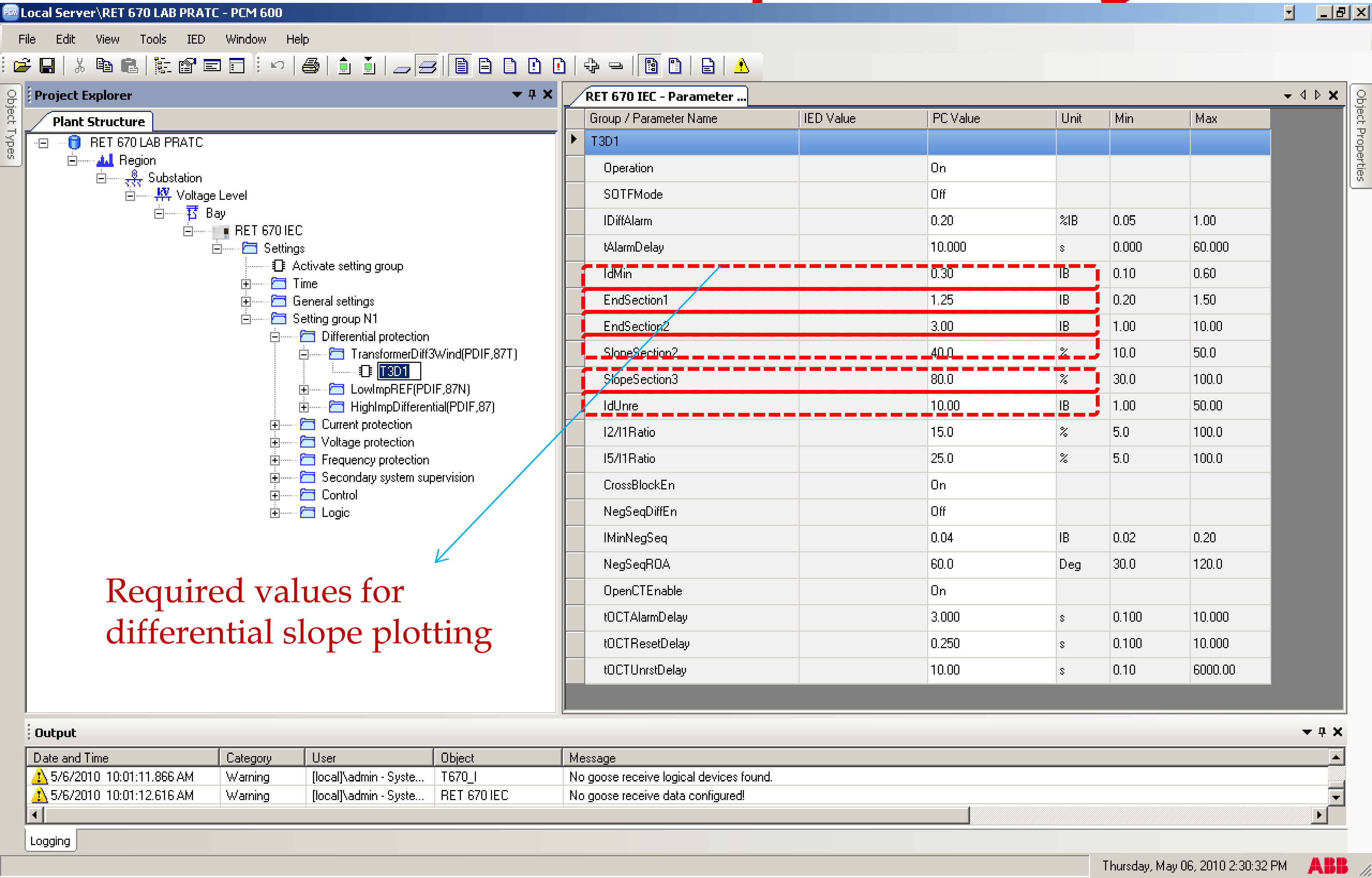
Antony RAJA, INOPC - 08/08/2013

RET 670
Differential Slope Plotting

Differential Slope Plotting



Differential Slope Plotting



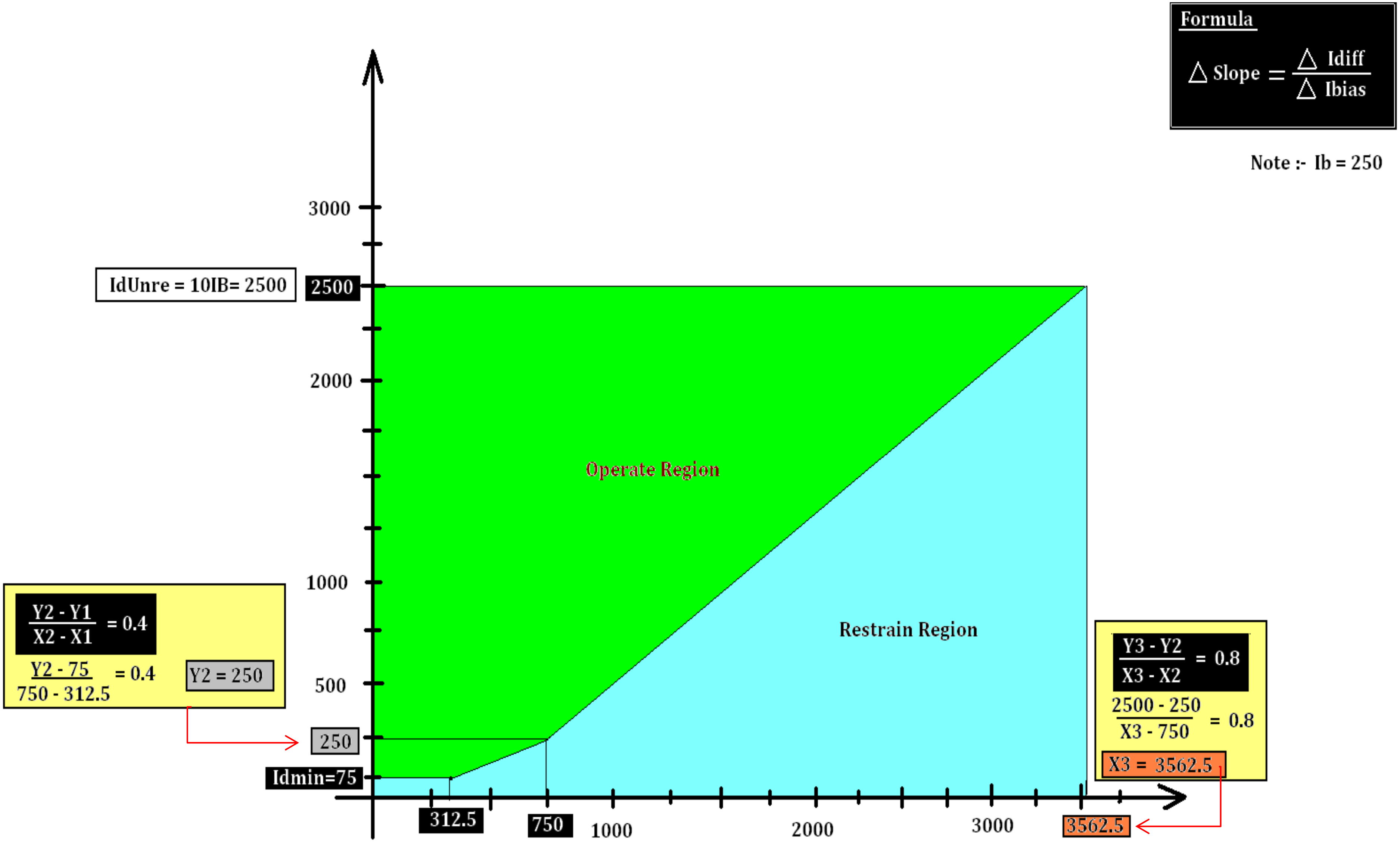
Required values for differential slope plotting

Differential Slope Ploting

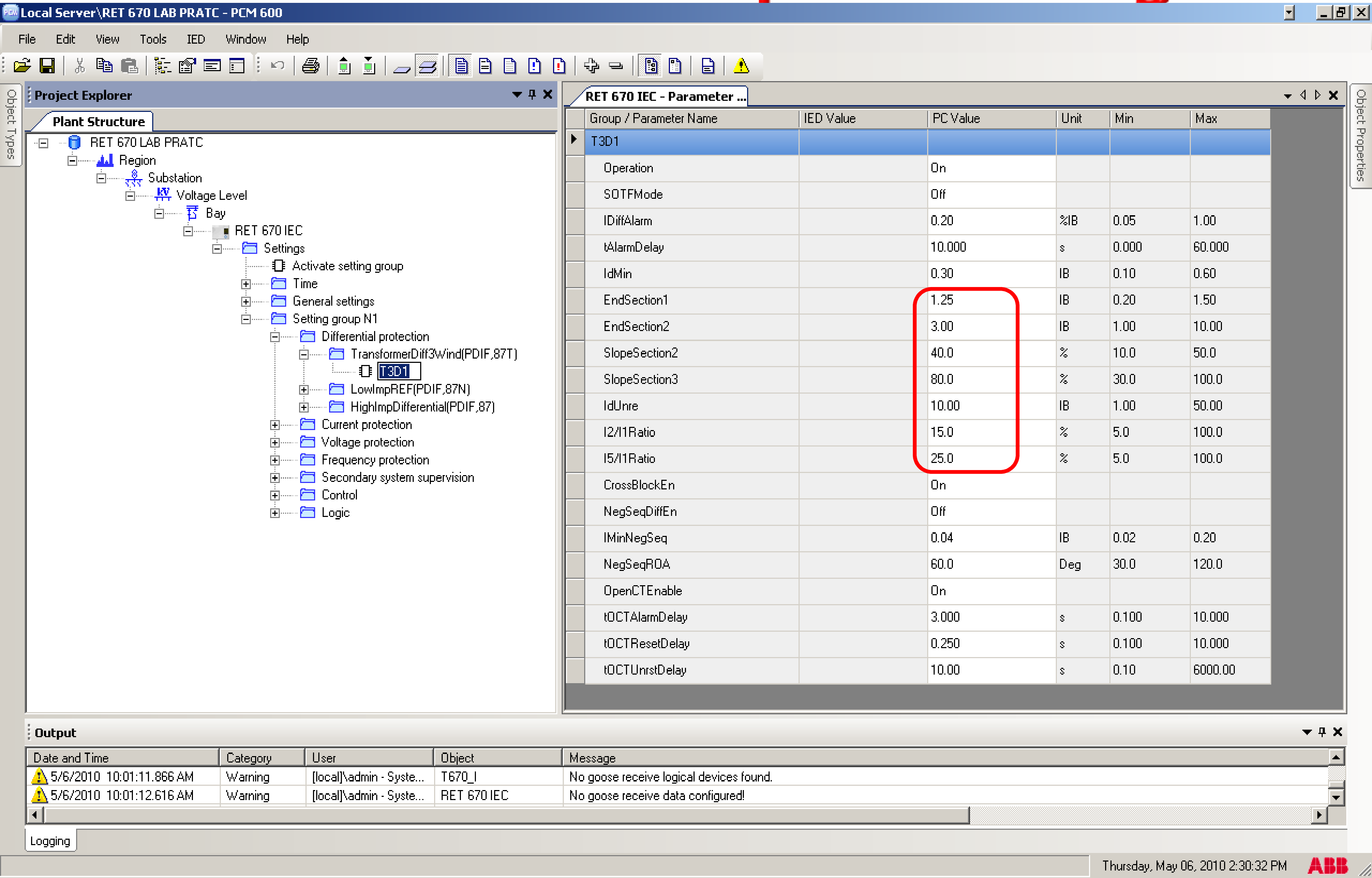
Given Values :-

1)	Ibias	=	250		
2)	Idmin	=	0.3 IB	=	75
3)	Endsection 1	=	1.25 IB	=	312.5
4)	Endsection 2	=	3.00 IB	=	750
5)	Slopesection2	=	40%		
6)	Slopesection3	=	80%		
7)	IdUnre	=	10 IB	=	2500
8)	X3	=	? Refer next slide		
9)	Y2	=	? Refer next slide		

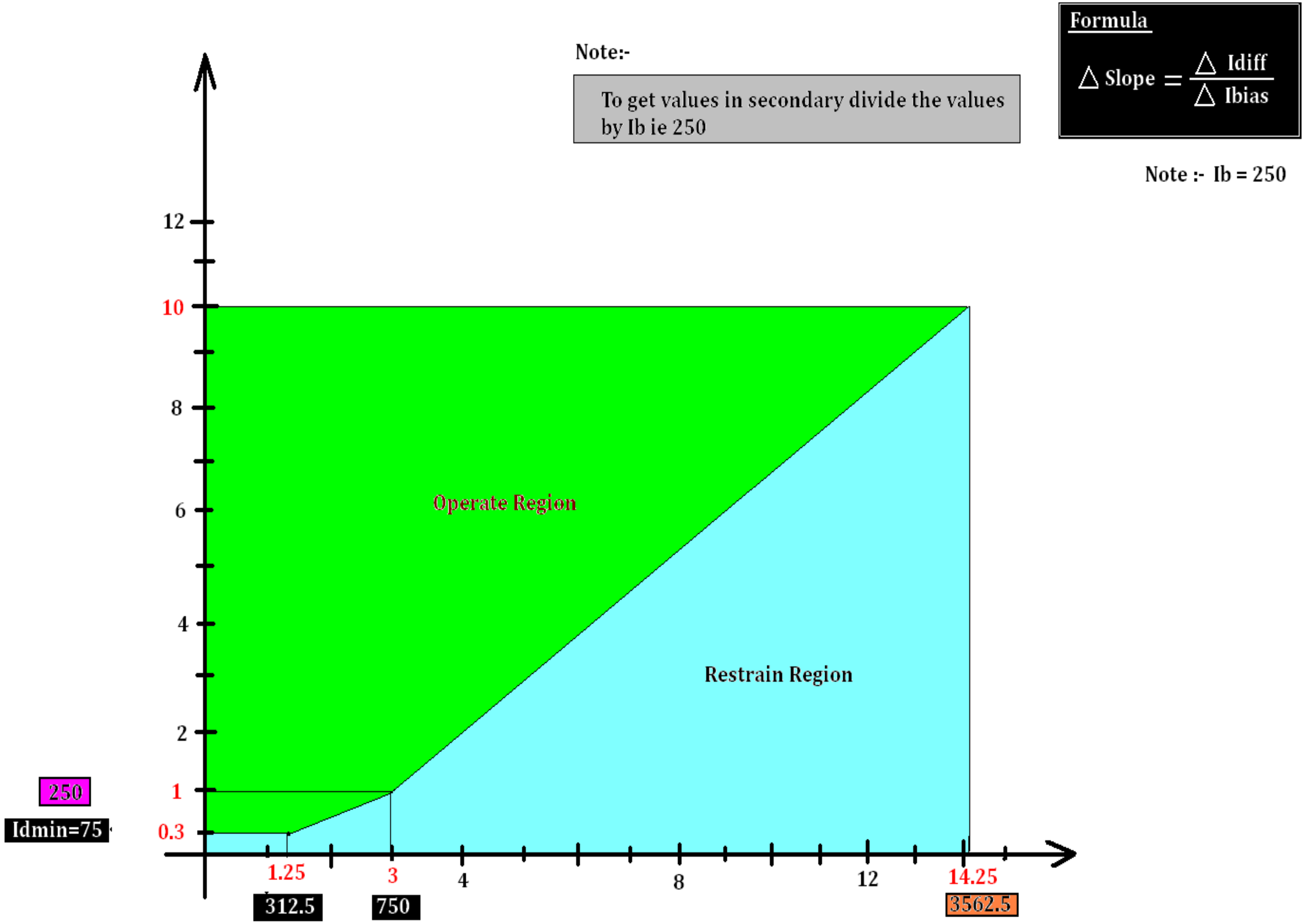
Differential Slope Plotting Procedure



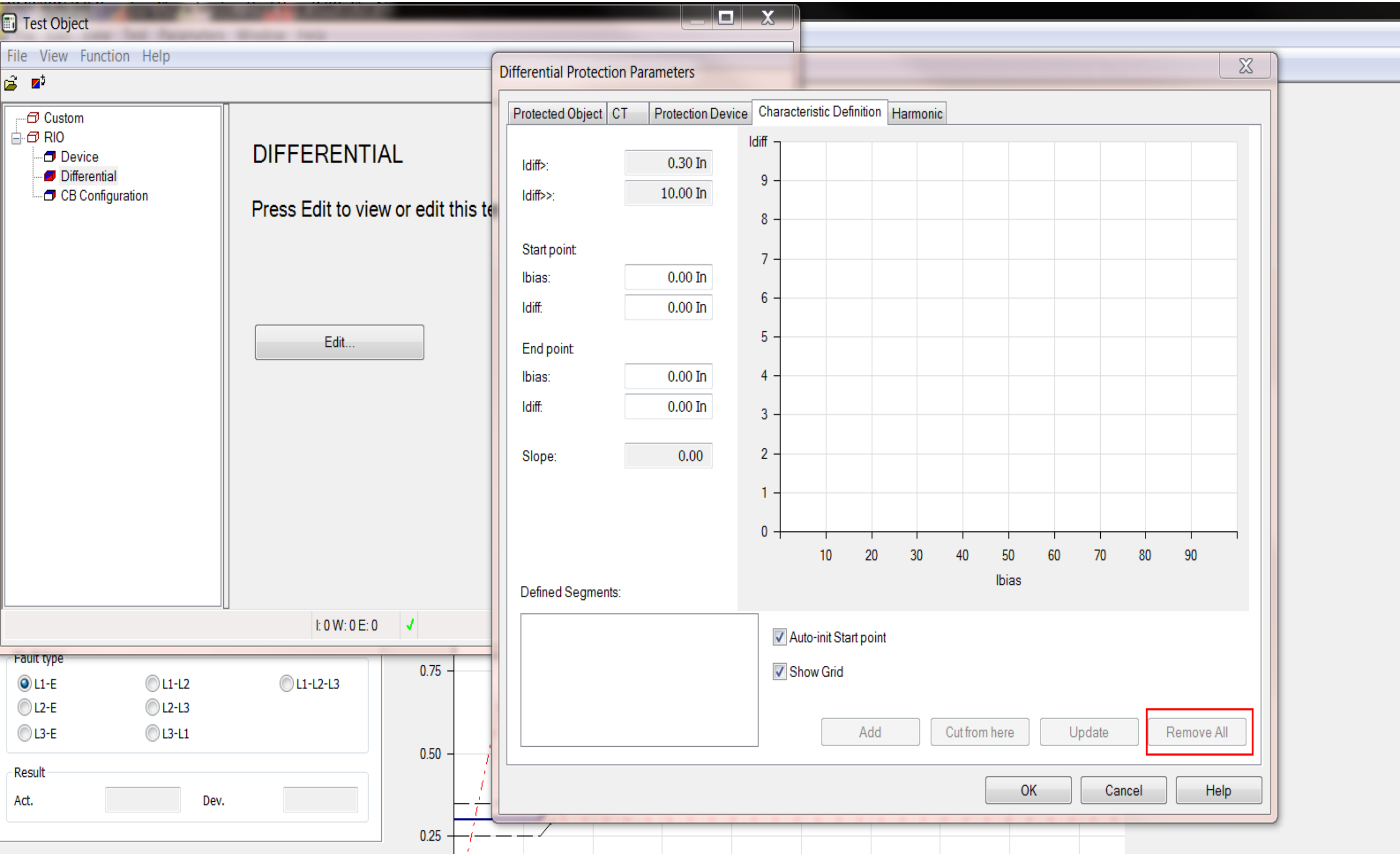
Differential Slope Plotting



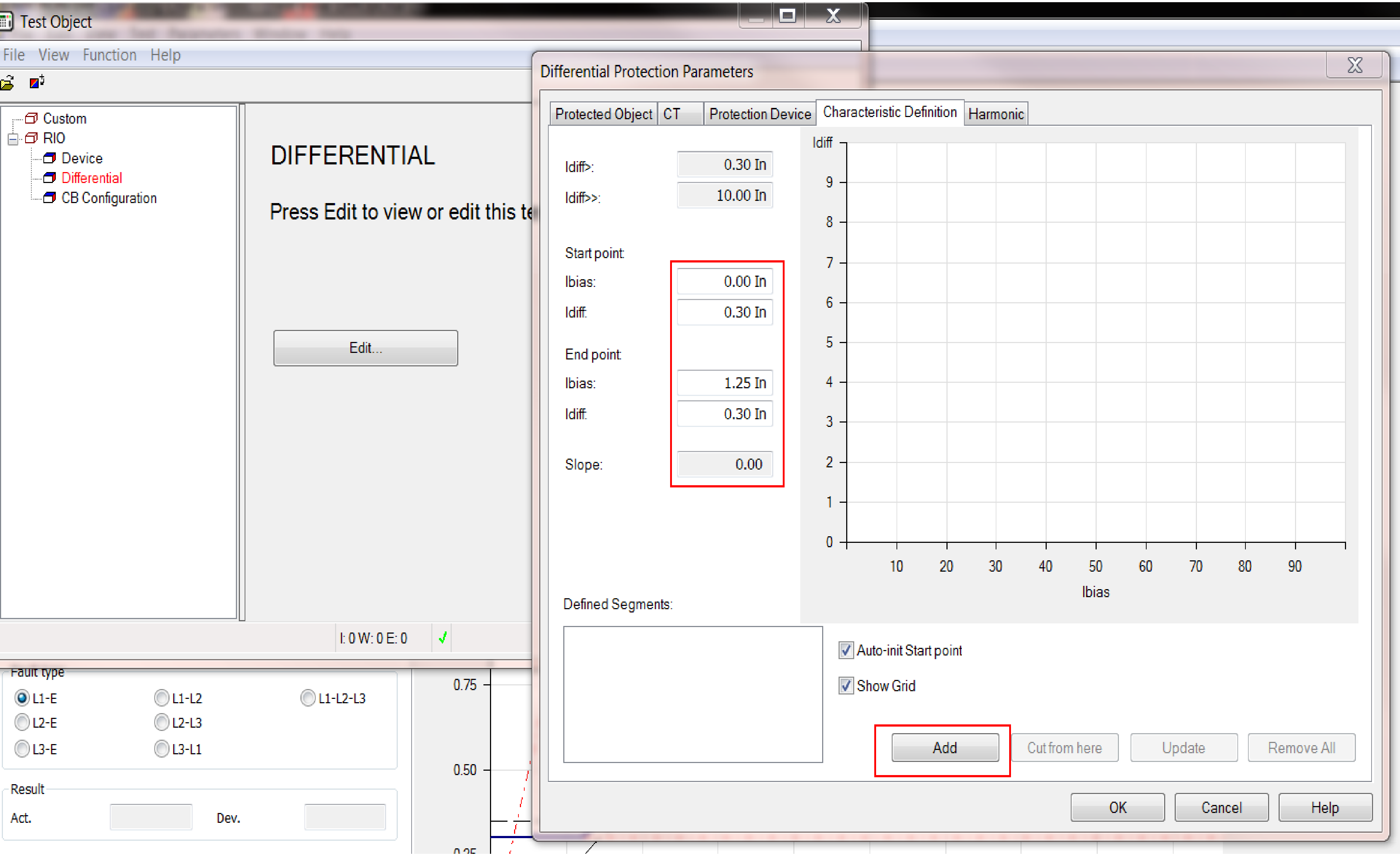
Differential Slope Plotting Procedure



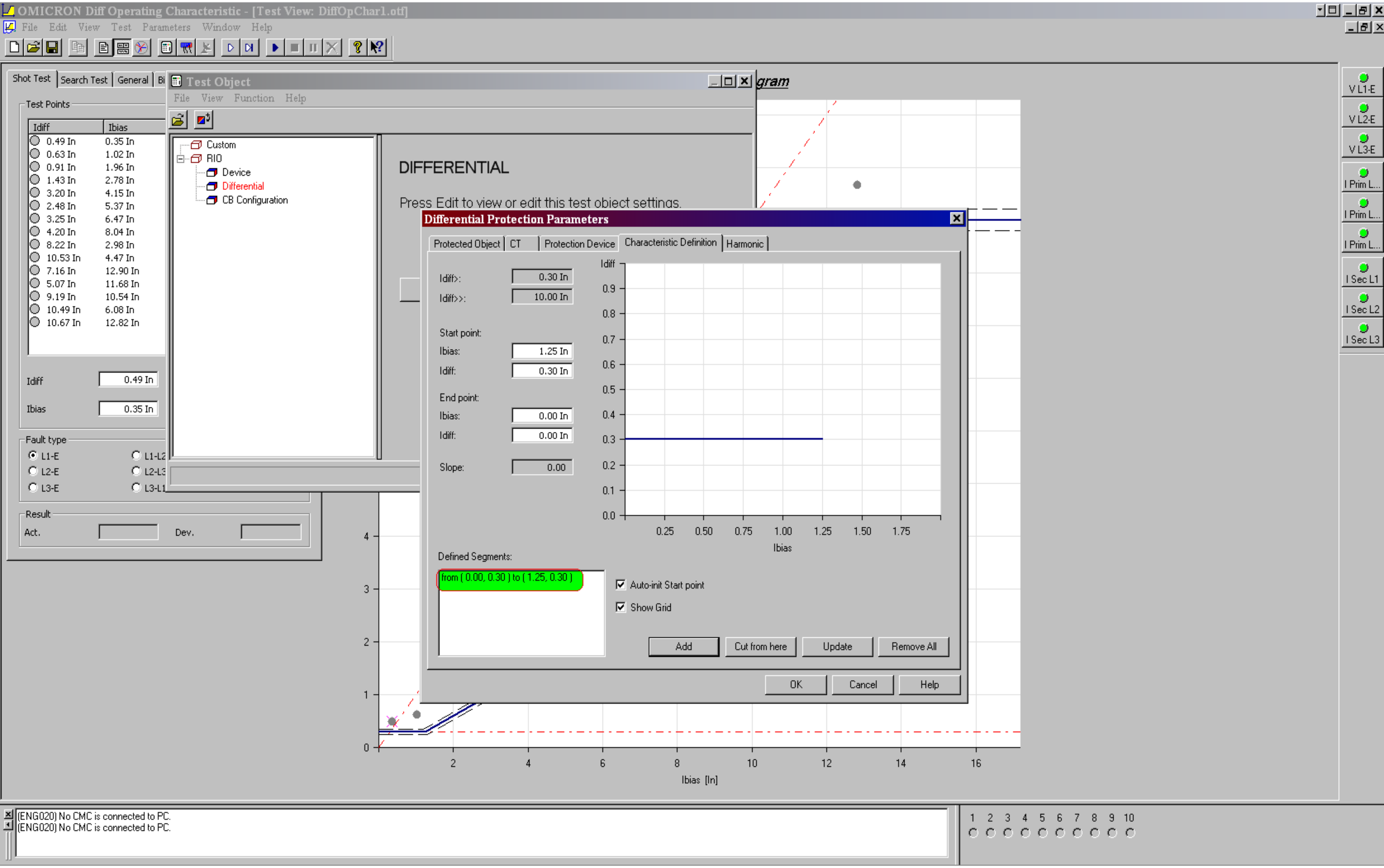
Differential Slope Plotting



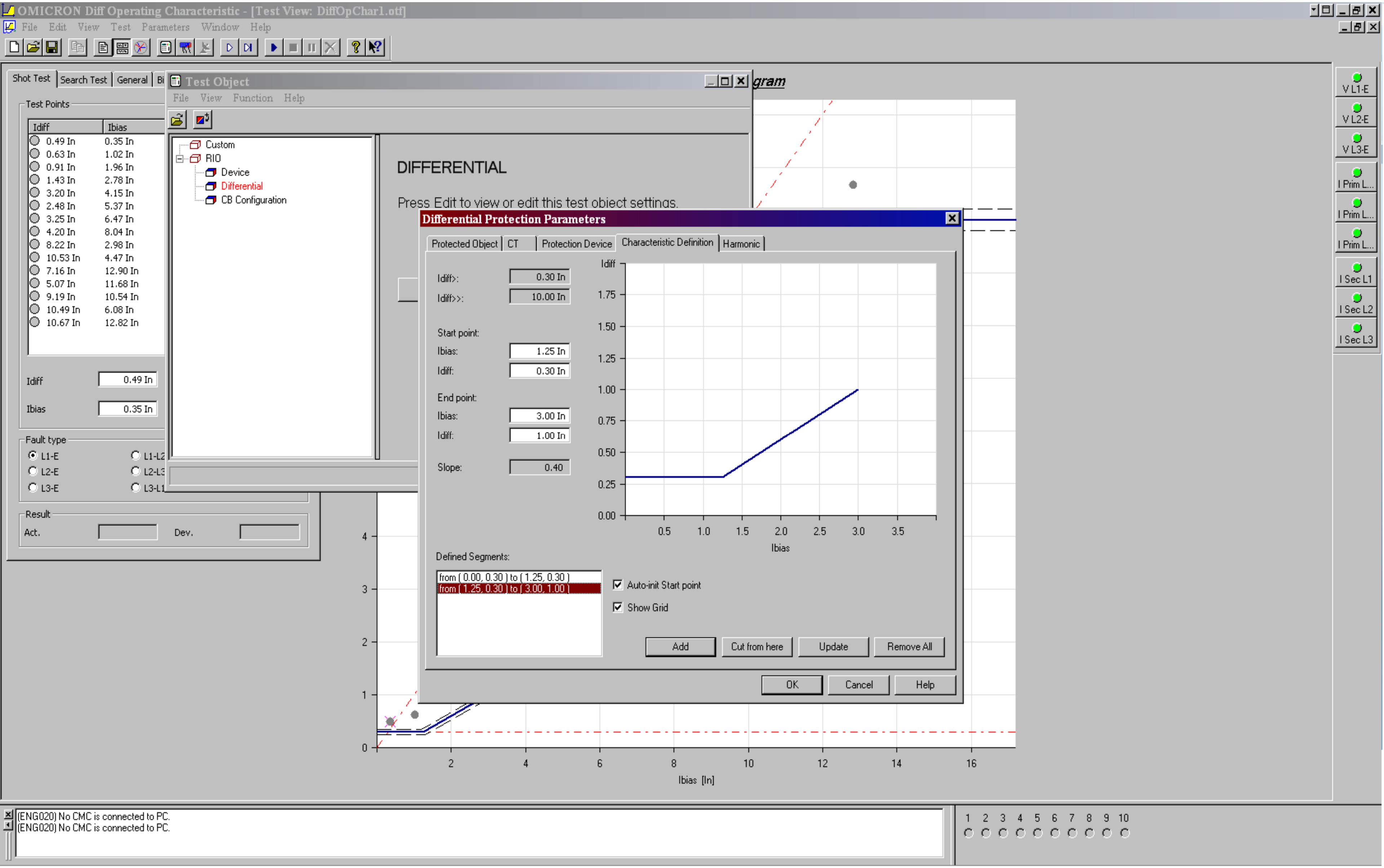
Differential Slope Plotting



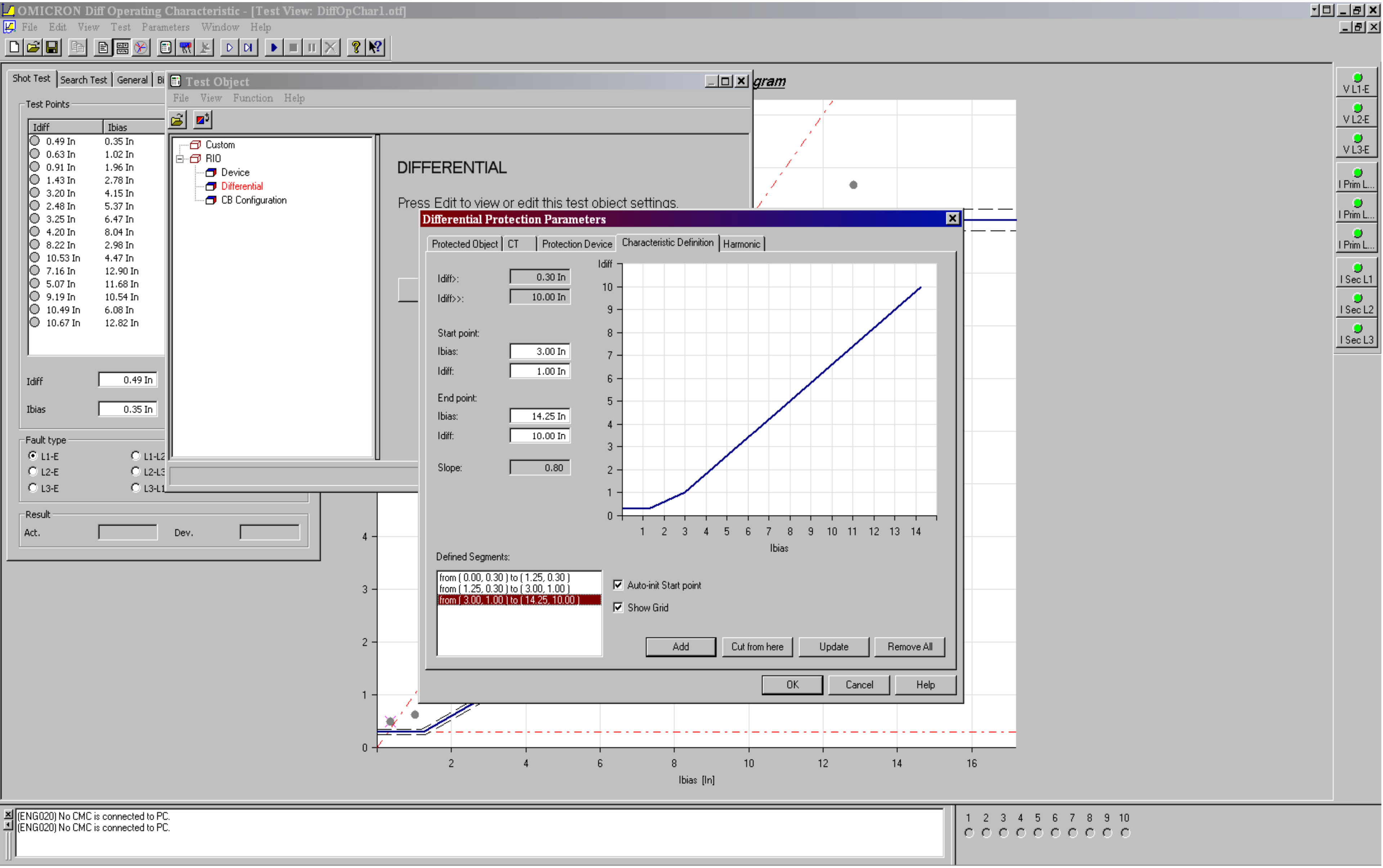
Differential Slope Plotting



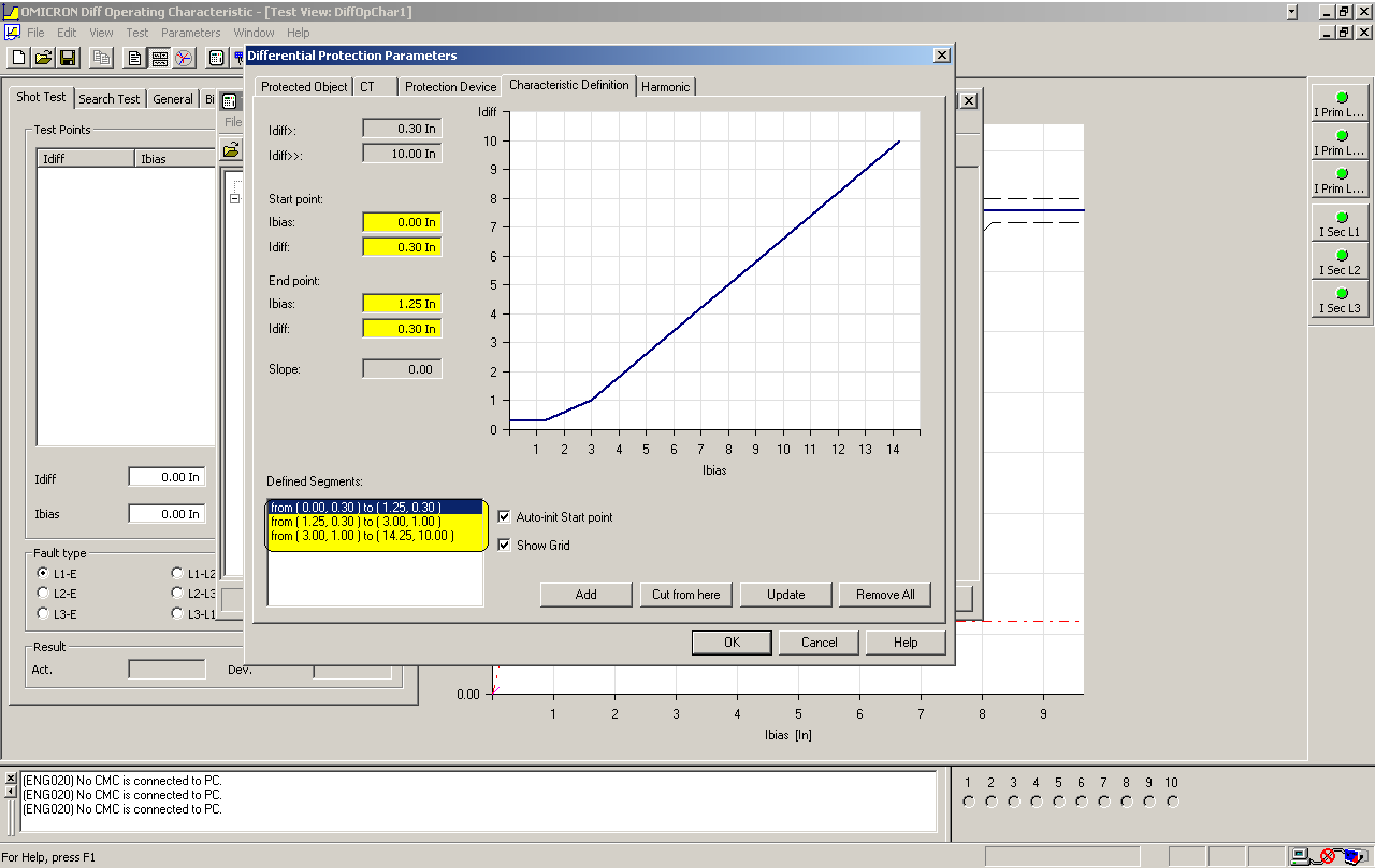
Differential Slope Plotting



Differential Slope Plotting



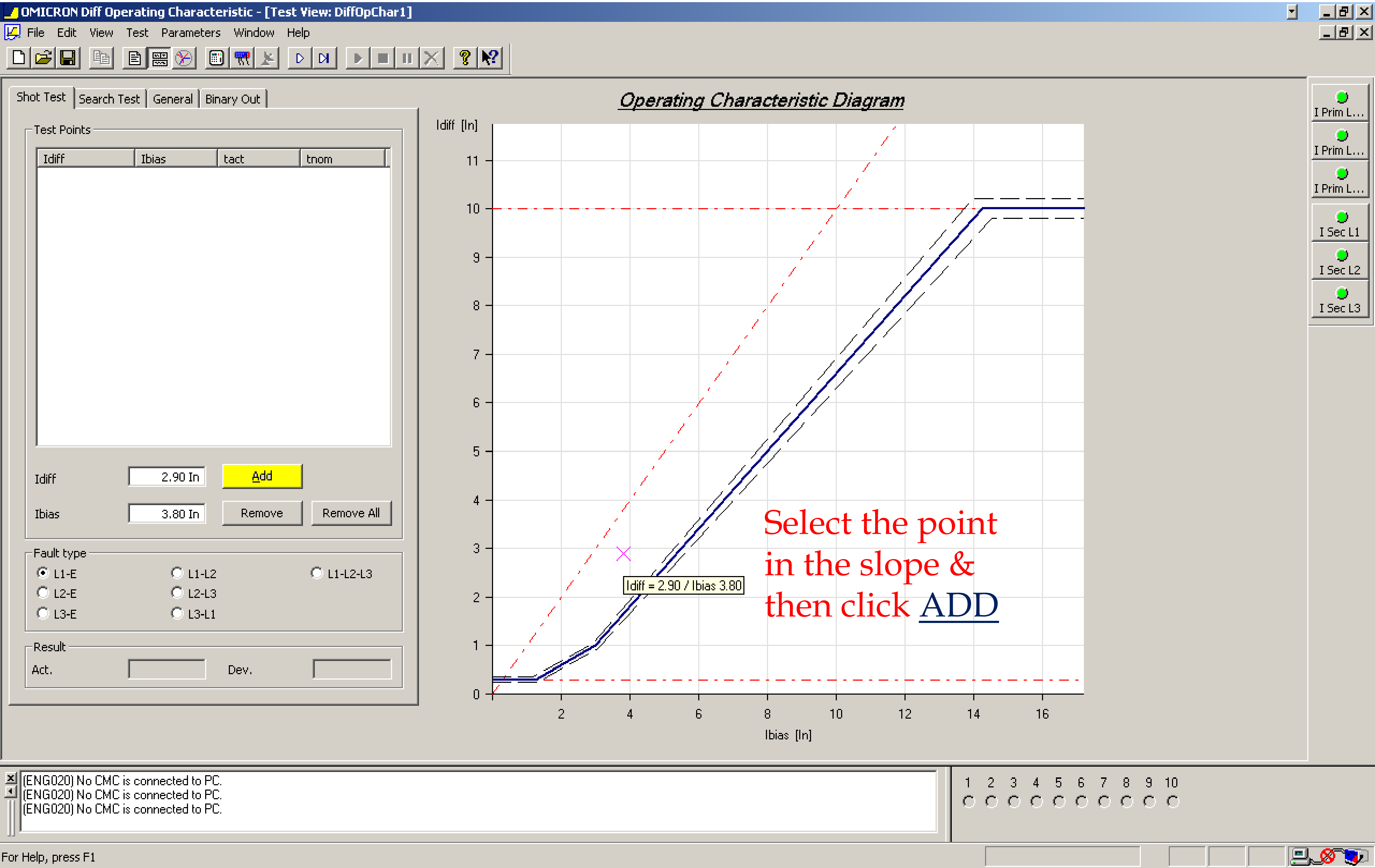
Differential Slope Plotting



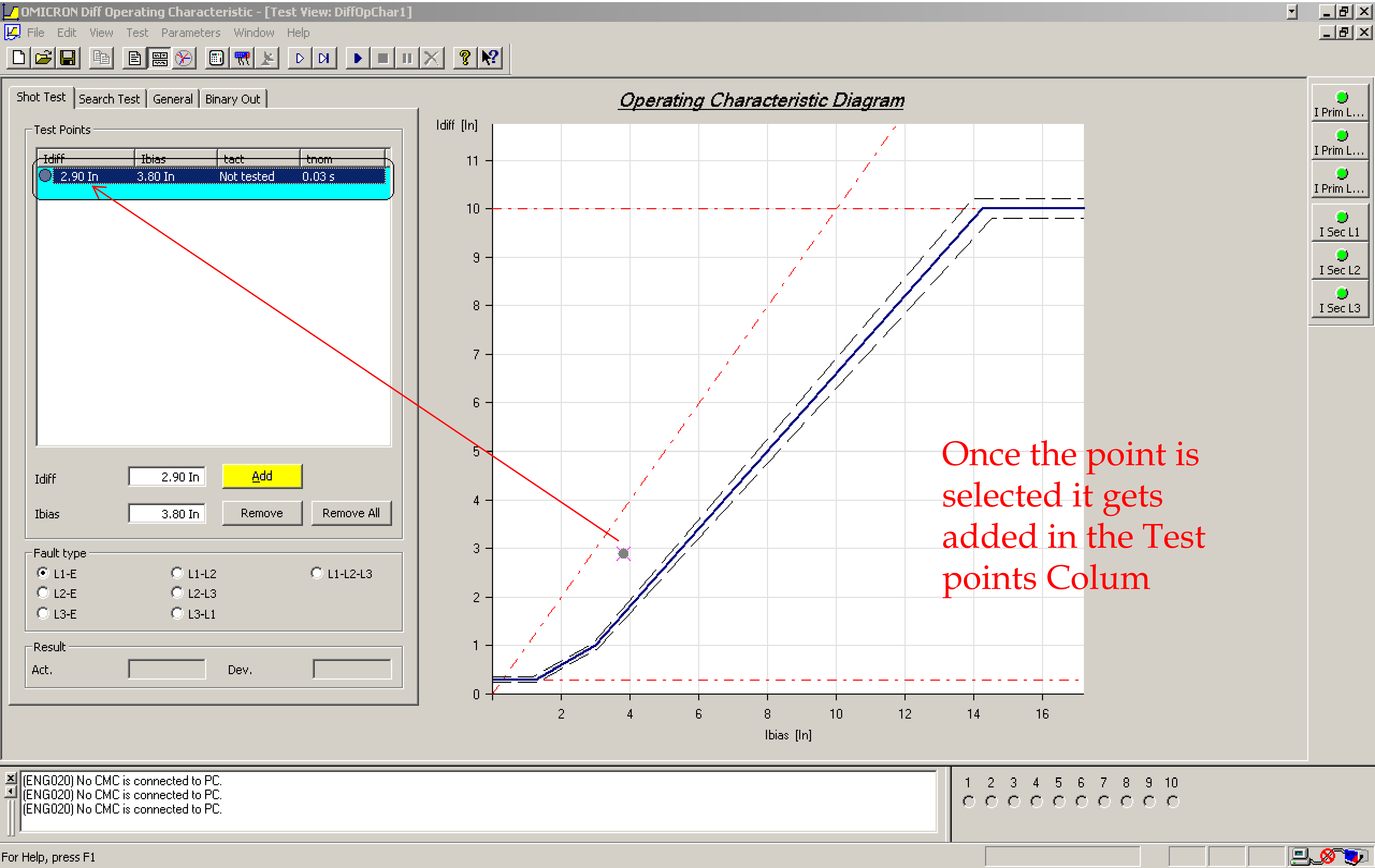
Antony RAJA, INOPC - 08/08/2013

RET 670
Differential Slope Testing

Differential Slope Testing

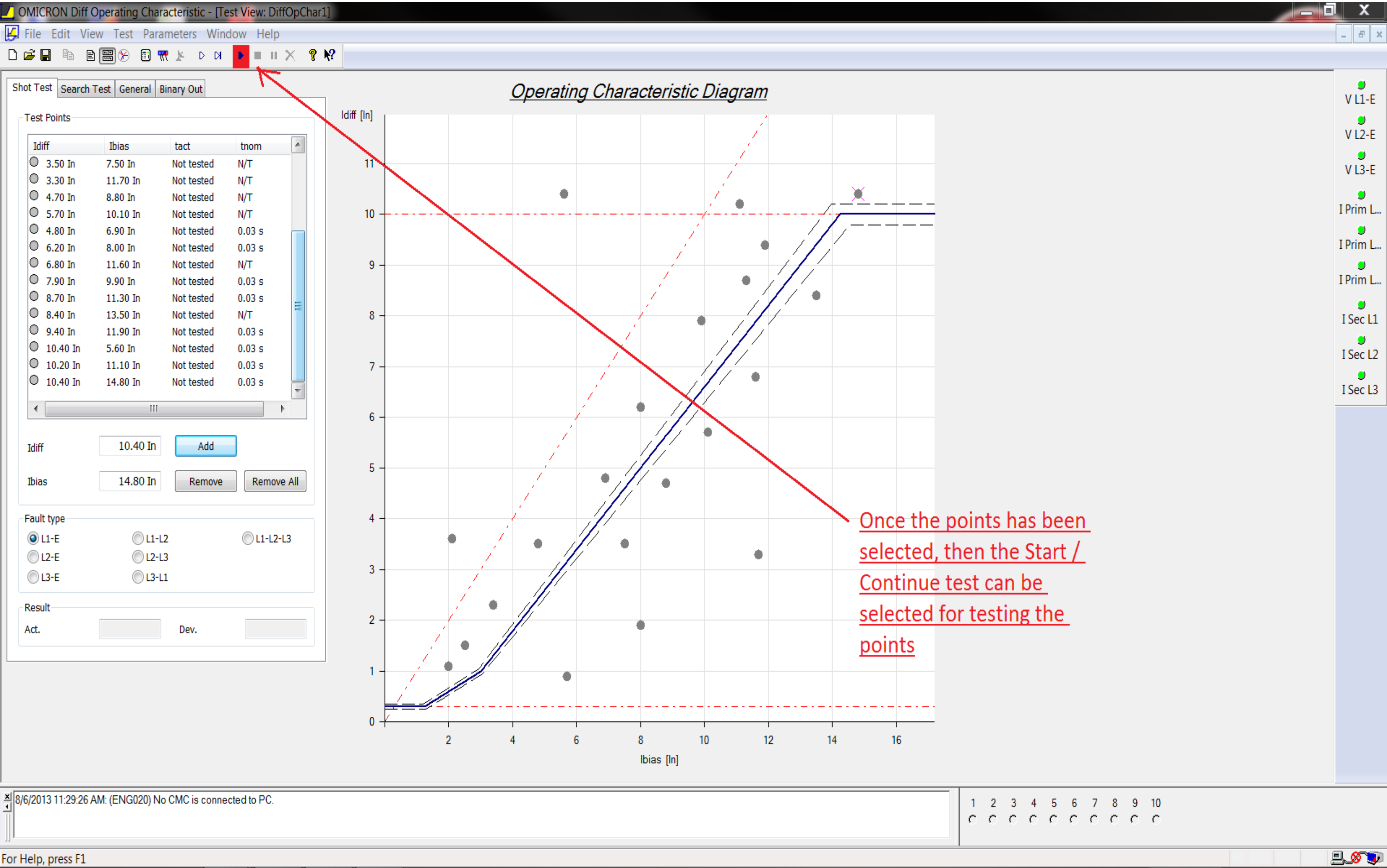


Differential Slope Testing

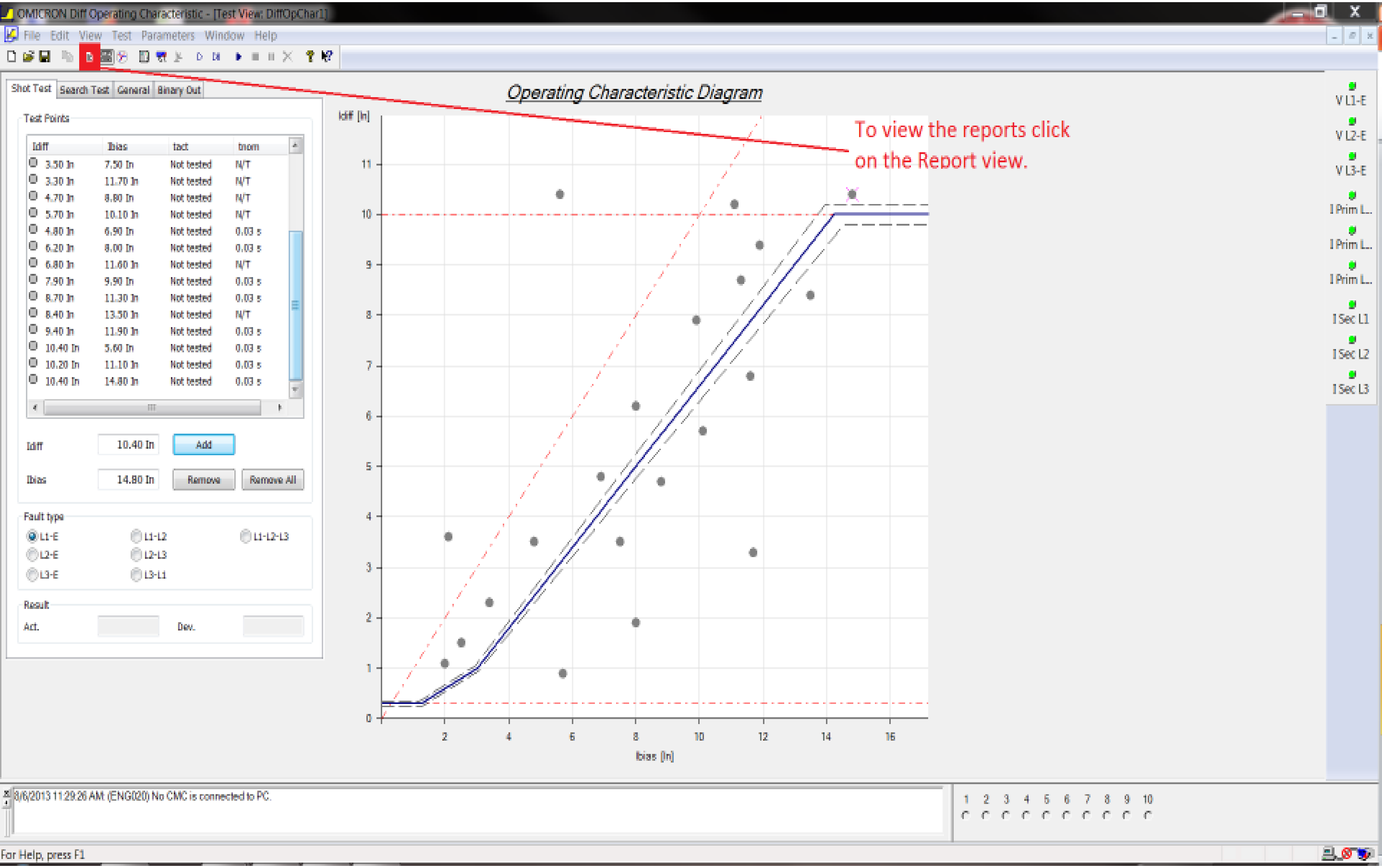


Once the point is selected it gets added in the Test points Colum

Differential Slope Testing



REPORT


OMICRON Diff Operating Characteristic - [Test View: DiffOpChar1]
File Edit View Test Parameters Window Help
Shot Test
Search Test
General
Binary Out
Operating Characteristic Diagram
To view the reports click on the Report view.
Test Points
Idiff Ibias tact tnom
3.50 In 7.50 In Not tested N/T
3.30 In 11.70 In Not tested N/T
4.70 In 8.80 In Not tested N/T
5.70 In 10.10 In Not tested N/T
4.80 In 6.90 In Not tested 0.03 s
6.20 In 8.00 In Not tested 0.03 s
6.80 In 11.60 In Not tested N/T
7.90 In 9.90 In Not tested 0.03 s
8.70 In 11.30 In Not tested 0.03 s
8.40 In 13.50 In Not tested N/T
9.40 In 11.90 In Not tested 0.03 s
10.40 In 5.60 In Not tested 0.03 s
10.20 In 11.10 In Not tested 0.03 s
10.40 In 14.80 In Not tested 0.03 s
Idiff 10.40 In
Add
Ibias 14.80 In
Remove
Remove All
Fault type
L1-E
L2-E
L3-E
L1-L2
L2-L3
L3-L1
L1-L2-L3
Result
Act.
Dev.
Idiff [In]
Ibias [In]
V L1-E
V L2-E
V L3-E
I Sec L1
I Sec L2
I Sec L3
8/6/2013 11:29:26 AM (ENG020) No CMC is connected to PC.
For Help, press F1

REPORT

RET diff chara full optipn lab.otf

Test Object - Differential Parameters

Protected Object:

Protected Object: Transformer

Vector Group: YD1Y0

Winding/Leg Name:	Primary	Secondary	Tertiary
Voltage:	220.00 kV	110.00 kV	10.50 kV
Power:	95.25 MVA	95.25 MVA	95.25 MVA
Starpoint Grounding:	Yes	No	Yes
Delta-connected CT:	No	No	No

CT:

Winding/Leg Name:	Primary	Secondary	Tertiary
CT Current Prim:	800.00 A	2500.00 A	3000.00 A
CT Current Sec:	1.00 A	1.00 A	1.00 A
CT Grounding:	tow. Prot. Obj.	tow. Prot. Obj.	tow. Prot. Obj.
Gnd CT Prim Current:	200.00 A	800.00 A	800.00 A
Gnd CT Sec Current:	1.00 A	1.00 A	1.00 A
Gnd CT Grounding:	n/a	n/a	n/a

Protection device:

Reference Winding: Primary

Ibias Calculation: max (Ip, Is) (K1 = 1.00)

Zero Seq. Elimination: IL-I0

Reference Current: PO nominal current

Ground CT Used: No

Disable Comb. char.: Yes

REPORT

Disable Comb. char.:	Yes		
		tdiff>:	0.03 s
Idiff>:	0.30 In	tdiff>>:	0.03 s
Idiff>>:	10.00 In		
		ttol rel:	3.00 %
Itol rel:	2.00 %	ttol abs:	0.01 s
Itol abs:	0.05 In		

Test Module

Name:	OMICRON Diff Operating Characteristic	Version:	2.30
Test Start:	06-Apr-2010 10:14:38	Test End:	06-Apr-2010 10:15:37
User Name:		Manager:	
Company:			

Test Settings:

Testing:	Primary / Secondary		
Max. Test Time:	1.50 s	Delay Time:	0.25 s
Prefault:	No		
Prefault current:	0.00 In	Prefault time:	0.000 s
Vout enabled:	No	Vout winding:	Primary
GPS/IRIG-B enabled:	No	GPS/IRIG-B side:	Primary

Binary Outputs

Bin. out 1:	0
Bin. out 2:	0
Bin. out 3:	0

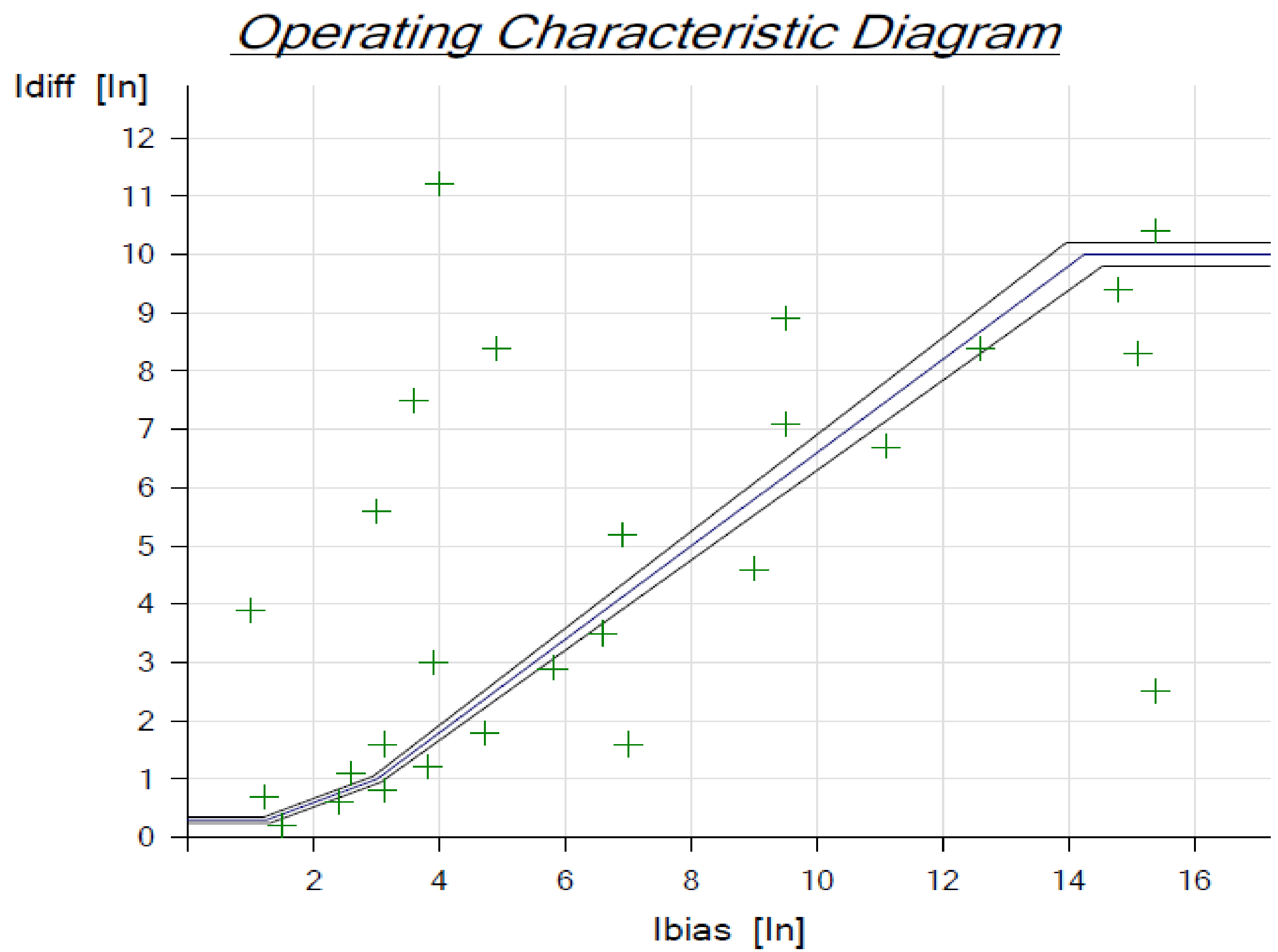
REPORT

Bin. out 4: 0

Test Results for Fault Type L1-E at Reference Side Primary

Idiff	Ibias	Nominal Trip Time	Actual Trip Time	State	Result
0.70 In	1.20 In	0.0300 s	0.0256 s	Tested	Passed
1.10 In	2.60 In	0.0300 s	0.0294 s	Tested	Passed
1.60 In	3.10 In	0.0300 s	0.0305 s	Tested	Passed
3.00 In	3.90 In	0.0300 s	0.0296 s	Tested	Passed
3.90 In	1.00 In	0.0300 s	0.0317 s	Tested	Passed
5.60 In	3.00 In	0.0300 s	0.0317 s	Tested	Passed
7.50 In	3.60 In	0.0300 s	0.0294 s	Tested	Passed
5.20 In	6.90 In	0.0300 s	0.0315 s	Tested	Passed
8.40 In	4.90 In	0.0300 s	0.0312 s	Tested	Passed
11.20 In	4.00 In	0.0300 s	0.0275 s	Tested	Passed
8.90 In	9.50 In	0.0300 s	0.0295 s	Tested	Passed
7.10 In	9.50 In	0.0300 s	0.0321 s	Tested	Passed
10.40 In	15.40 In	0.0300 s	0.0268 s	Tested	Passed
9.40 In	14.80 In	N/T	N/T	Tested	Passed
8.40 In	12.60 In	N/T	0.0311 s	Tested	Passed
8.30 In	15.10 In	N/T	N/T	Tested	Passed
6.70 In	11.10 In	N/T	N/T	Tested	Passed
4.60 In	9.00 In	N/T	N/T	Tested	Passed
3.50 In	6.60 In	N/T	N/T	Tested	Passed
2.90 In	5.80 In	N/T	N/T	Tested	Passed
1.80 In	4.70 In	N/T	N/T	Tested	Passed
1.20 In	3.80 In	N/T	N/T	Tested	Passed
0.80 In	3.10 In	N/T	N/T	Tested	Passed
0.60 In	2.40 In	N/T	N/T	Tested	Passed
0.20 In	1.50 In	N/T	N/T	Tested	Passed
1.60 In	7.00 In	N/T	N/T	Tested	Passed
2.50 In	15.40 In	N/T	N/T	Tested	Passed

REPORT



Shot	1	2	3	4	5	6

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for a better world™